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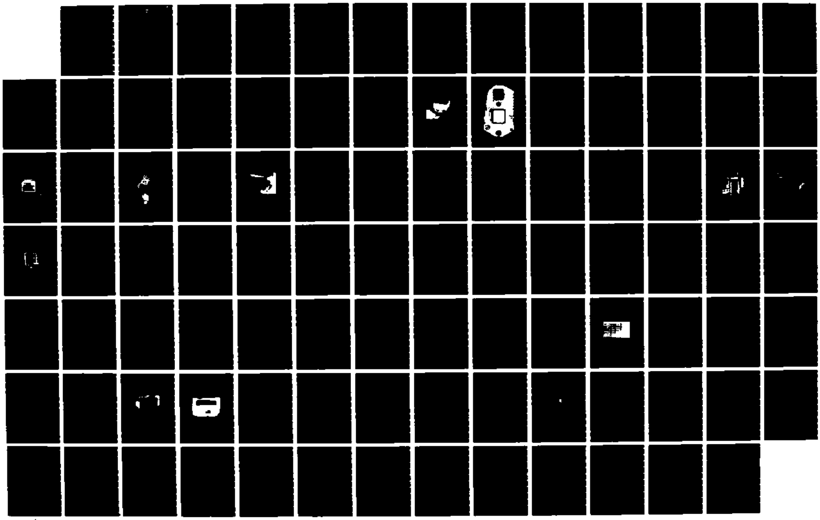

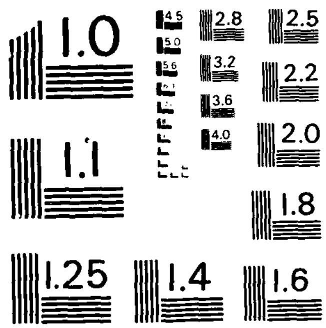

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Battelle
Columbus Division

Report

SOLDIER DATA TAG
STUDY EFFORT
Phase 2 - Technical Evaluation
of Candidate Systems

APPENDIX F

to

U.S. Army Soldier Support Center
ATZI/DDS (Mr. Occhialini)
Fort Benjamin Harrison, IN 46216

December 31, 1985

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FINAL REPORT

Submitted Under
Contract Number DATB60-84-C-0146

on

SOLDIER DATA TAG
STUDY EFFORT
Phase 2 - Technical Evaluation of Candidate Systems

APPENDIX F

to

U.S. Army Soldier Support Center
ATZI/DDS (Mr. Occhialini)
Fort Benjamin Harrison, IN 46216

December 31, 1985

by
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A-1

The views, opinions, and findings contained in this document are those of the authors and should not be construed as official Department of the Army position, policy, or decision unless so designated by other official documents.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The scope of the current study effort is directed at an analysis of the Soldier Data Tag System concept during both wartime and peacetime scenarios. The current study is directed primarily at Army personnel systems, medical systems, and financial systems.. However, it is likely that the SDT system will have wider applications. For example, in an earlier study conducted for DoD in the logistics area, Battelle identified many feasible, cost-effective applications for portable

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data carriers. These included inventory tags, maintenance and repair records, and manifest lists.

Data acquisition and analysis for the project was limited to that available on the [illegible] system concept demonstrations and emerging DoD automation systems. No detailed system design or laboratory experiments were performed.

The benefits from the [illegible] would be expected to lie in the areas of: improved readiness in peacetime, redundancy and backup of data for the [illegible] automation systems, overall improvement to the speed and accuracy of [illegible] data entries, ability to provide a transfer data record ([illegible]) which replaces the error-prone paper system, and improved information processing on the battlefield.

As a result of the study, the major peacetime benefits identified [illegible] enhancements to the automated Army [illegible] on-line. These enhancements include:

[illegible] without keyboard data entry; [illegible] data [illegible] system is unavailable; [illegible] data to new locations in [illegible]

ability to [illegible] exchange problems that [illegible] to a new station [illegible]

EXECUTIVE SUMMARY

Through the conduct of Battelle's original study for the Army under Contract Number DATB60-84-C-0146, the need for an evaluation of candidate data carrier technologies was identified. This report describes an evaluation of several candidate technologies that could be considered for use in a Soldier Data Tag System. The technologies selected for evaluation are representative of existing off-the-shelf portable data carrier systems that are in, or near, commercial use today. It should be noted that many firms also offer similar systems, and the specific systems reviewed in this report should, for the most part, be examined in the light of this fact. The major driving factor in the selection of specific systems was the ability to procure them at reasonable cost in the time frame of the study.

In order to investigate representative systems in a timely and cost-effective manner, the depth of the study was appropriately limited in scope. The evaluation was performed by "screening" the technologies against a set of pragmatic tests, experiments, and design reviews focused on the key technical aspects of the particular system. The end goal was to gather data that could aid in estimating the applicability of the system to SDT and their survivability in the face of commonly expected hazards.

The primary portion of this project was spent in the evaluation of the SDT prototype hardware supplied by the Datakey Corporation. This was because the Army has had several years of experience with this system, and it has gone through design modifications based on its use in this environment. Valuable "lessons learned" should arise from a detailed, objective analysis. In addition, the Army is likely to continue to conduct demonstration experiments based on this technology in the near-term tests because a significant inventory of devices are on hand. Tests conducted with these tags would not necessarily be indicative of endorsement by the

Army, but would represent a fast and convenient method of testing ancillary issues associated with the logistical effectiveness of the SDT system. Furthermore, these devices provide an initial operational capability to any unit "testing" the concept.

Battelle also performed physical tests and design evaluations of two other systems that are representative of the technology in present day portable data carriers: Drexler Technology Corporation's optical storage card system, and AT&T's non-contact memory card system. The extent of these reviews were influenced by the type of equipment procured, the amount of documentation available, and data from the vendor on pertinent tests.

An examination of smart card technology was also performed based on data provided by Micro Card Incorporated. Battelle was not able to procure devices for physical testing, however, an examination of available documentation provided by Micro Card allowed for a brief review of the appropriateness of this technology.

In the opinion of the project team, none of the systems reviewed can currently meet all of the anticipated Soldier Data Tag system needs. The current prototype system exhibits some reliability problems and non-robust design techniques. The optical card is not yet a commercial-ready product and, hence, there are uncertainties about its performance in this application. For example, its data storage technique will probably not survive the harsh Army application environment. The memory card products currently are not properly packaged and do not yet exhibit the required storage capacity.

While the above comments reveal that a system is not commercially ready today, the objective SDT system is technically feasible. Engineering changes and a combination of various technologies are required in order to develop an Army SDT system that will meet the requirements. Based on the evaluation of representative technologies, the Battelle project team has identified a set of desirable technologies that should be considered for the objective SDT system. These include:

- The use of packaging materials and assembly techniques that provide proper protection for the embedded electronics.

- The use of non-contact data and power transfer techniques to increase the reliability of the system.
- The use of electrically erasable memory so that the life expectancy of the tag is not limited to a maximum number of transactions.
- The development of tag interface devices that is hermatically sealed and capable of surviving harsh environments and mechanical shock.
- The adoption of a design approach that supports the straightforward integration of new technologies (that increase the capability of the SDT system) as they become available.

The cost-effective SDT system solution may be stimulated by the evaluation presented in the report, and through subsequent technology evaluations as the design process continues. Further improvements may also arise by examining off-the-shelf technologies.

For example, portable data carrier systems are emerging in a wide variety of areas, including those intended to operate in harsh environments similar to the Army's application. Taking advantage of these off-the-shelf approaches may allow the cost of the data tag to be reduced due to the very high volumes involved in commercial use. For example, manufacturing inventory control applications and transaction card applications are expected to involve hundreds of millions of devices. Modification to these systems to make them compatible with the Army's needs is likely to be quite feasible, and may well represent a cost-effective and quick-turnaround development alternative.

At this point in the development, it is recommended that the Army proceed with an in-depth requirements study to determine a specification for the objective SDT system. This should involve the following activities:

- **In-depth analysis of the potential applications to determine information processing requirements.** This will enable the Army to determine the storage capacity requirement for the tag

and the interface requirements for the tag interface device. Also, exact environmental specifications can be developed.

- **Tag data base configuration study.** Once fielded, it is anticipated that a soldier data tag concept will attract new applications as well as isolated applications that will "piggyback" on the SDT. A method of data management must be adopted so that the applications can co-exist without destroying the information integrity of the tag system in general. The philosophy for this configuration should be examined in parallel with the applications study mentioned in Item 1.

- **Market survey.** There are many portable data carrier systems available today that should be examined in light of the Army's application. The first step in this area would be to identify critical issues and criteria to be evaluated during the market survey. Following this, portable data carrier manufacturers should be interviewed in depth to determine their ability to satisfy the requirements.

- **Demonstration experiments.** Continued demonstration experiments should be pursued using the existing prototype tags in order to quickly evaluate the operational concepts. In addition, demonstration experiments based on other off-the-shelf portable data carrier designs should be initiated to test alternative technical concepts.

ACKNOWLEDGEMENTS

Battelle would like to acknowledge the assistance of Mr. Chris Occhialini, the Contracting Officer's Representative, for his guidance and assistance in this effort. We would also like to thank the variety of military and industrial participants whose input to this report was invaluable.

In addition, Battelle would also like to thank the following individuals for providing equipment and information for the study effort: Mr. Archie Paulson, of Datakey Corporation; Mr. Drew Karkow, Mr. Jim Lensch, and Mr. Martin Stevenson of AT&T Corporation; and Mr. Jeff Lang of Micro Card Technologies, Inc.

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1.0 INTRODUCTION

This report presents the results of Battelle's Phase II study and is provided as an Appendix to the **Soldier Data Tag Study Effort Final Report, Contract No. DATB60-84-C-0146,** completed on June 10, 1985. It presents a technical evaluation of several representative portable data carrier technologies that are being considered for the Soldier Data Tag System.

1.1 Background

Much of the basic background information concerning the objective and purpose of the Army's Soldier Data Tag (SDT) System is included in the above-referenced report and is not repeated here. Through the conduct of Battelle's original study for the Army, the need for a design review of the Army's SDT Prototype System was identified.

This prototype, manufactured by Datakey Corporation, has been in use for several years in various demonstration experiments, and has been subject to design modifications over this period. It was the opinion of the Army that a review of the prototype system could reveal many important "lessons learned" that could be applied in future implementations of the SDT system. The technical risks associated with near-term pilot applications, as well as any subsequent Army-wide implementation, could also be minimized.

Several other portable data carrier technologies also exist that may be able to meet the requirements of the objective SDT system. These include the smart card and the optical data card. For this reason, it was also determined that any technical evaluation should also include an investigation of the strengths and weaknesses of other candidate technologies.

A cost-effective SDT system solution may be stimulated by the evaluation presented in the report, and through subsequent technology evaluations as the design process continues. Further improvements may also arise by examining off-the-shelf technologies.

For example, portable data carrier systems are emerging in a wide variety of areas, including those intended to operate in harsh environments similar to the Army's application. Taking advantage of these off-the-shelf approaches may allow the cost of the data tag to be reduced due to the very high volumes involved in commercial use. For example, manufacturing inventory control applications and transaction card applications are expected to involve hundreds of millions of devices. Modification to these systems to make them compatible with the Army's needs is likely to be quite feasible, and may well represent a cost-effective and quick-turnaround development alternative.

1.2 Objective and Scope

The objective of this SDT Phase II Study Effort was to provide an evaluation of several candidate technologies being considered for use in the Objective Soldier Data Tag System. In order to investigate representative systems in a timely and cost-effective manner, the depth of the study was appropriately limited in scope. The evaluation was performed by "screening" the technologies against a set of pragmatic tests, experiments, and design reviews focused on the key technical aspects of the particular system. The end goal was to gather data that could aid in estimating survivability of the systems in the face of commonly expected hazards.

The evaluation and technical review of each data carrier system was conducted through a series of physical tests designed to identify major advantages and disadvantages of the system design approach. Experiments and design reviews were established to address the following questions:

- Can the data carrier be fabricated in a package size that is appropriate for the Army's needs?
- Will the encasement material survive the expected environment?
- Will data integrity of the system be maintained after exposure to expected hazards?
- Is the information processing capability of the system consistent with the requirements of the Army?

Good laboratory practice was utilized on all experiments conducted, and the test procedures are documented so that they can be reproduced by another laboratory if desired. The results of these activities often resulted in qualitative data, and these data were subsequently interpreted by a Battelle project team with experience in portable data carrier technology.

A selection of the "most appropriate" system or technology was not performed in this study. Rather, it is the intent of the study that the evaluations and technology comparisons will aid the Army in the identification of a technical approach that offers the best overall performance for the objective SDT system.

1.3 Research Approach

The Battelle project team for this study effort consisted of a multidisciplinary group with expertise in electronics, microprocessor technology, memory card systems, and materials analysis. This team also participated in the Phase I SDT study effort and was therefore familiar with the overall Army objectives for the system.

Physical testing of the hardware and qualitative design review of the overall system were the primary research methods. Materials tests were designed to determine how well the encasement material for the data carrier resists wear, shock, moisture, temperature extremes and cycling, and exposure to common chemicals. Data integrity tests were designed to

examine if the data tag's portable memory would remain functional and error-free after subjection to similar hazards.

The overall design review was accomplished by examining the equipment and available supporting documentation and comparing it to good design practices. Operability, expected reliability, and physical robustness were among the issues examined in this aspect of the study.

The results of the design reviews and physical tests were analyzed and used as the basis for a technology comparison. This comparison is intended to identify technological approaches for various aspects of the system (e.g. contact vs. non-contact, memory technique, etc.) that can be used in the objective SDT system.

1.3.1 Systems Selected for Evaluation

The evaluation of representative data carrier systems was influenced heavily by the ability to procure the systems quickly, the level of documentation available, and whether it represented a potential candidate for the objective SDT system.

The primary portion of this project was spent in the evaluation of the SDT prototype hardware supplied by the Datakey Corporation. This was because the Army has had several years of experience with this system, and it has gone through design modifications based on its use in this environment. Valuable "lessons learned" should arise from a detailed, objective analysis. In addition, the Army is likely to continue to conduct demonstration experiments based on this technology in the near-term tests because a significant inventory of devices are on hand. Tests conducted with these tags would not necessarily be indicative of endorsement by the Army, but would represent a fast and convenient method of testing ancillary issues associated with the logistical effectiveness of the SDT system. Furthermore, these devices provide an initial operational capability to any unit "testing" the concept.

These tests were performed using approximately 75 Datakey tags and two Tag Interface Devices. A variety of tests, each usually involving two or more tags, were performed as described in the next section. An attempt was made to only use each device in one test once so that subsequent tests would not be influenced by the stress induced on the tag in the previous test.

Battelle also performed physical tests and design evaluations of two other systems: the Drexler Technology Corporation's optical storage card system, and AT&T's non-contact memory card system. The extent of these reviews were influenced by the type of equipment procured, the amount of documentation available, and data from the vendor on pertinent tests. Some important tests had already been conducted by the vendors. These tests were not repeated at Battelle, but their results are interpreted in light of the end goal for the SDT system.

An examination of smart card technology was also performed based on data provided by Micro Card Incorporated. Battelle was not able to procure devices for physical testing, however, an examination of available documentation provided by Micro Card allowed for a brief review of the appropriateness of this technology.

1.4 Organization of the Appendix

This Appendix has been organized as follows:

- Section 1.0 - Introduction
- Section 2.0 - Technology Evaluation
    - Section 2.1 - Overview
    - Section 2.2 - Datakey SDT Prototype System
    - Section 2.3 - Drexler Optical Card System
    - Section 2.4 - AT&T Memory Card System
    - Section 2.5 - Micro Card Memory Card System
- Section 3.0 - Conclusions and Recommendations

2.0 TECHNOLOGY EVALUATION SECTION

2.1 Overview

This section of the report describes the technical evaluation of several candidate portable data carrier systems. These systems were selected as being representative of existing products and it should be noted that inclusion in this report does not imply an endorsement by either the Army or Battelle. The systems evaluated during the study include:

- Datakey Corporation's SDT prototype system,
- Drexler Technology Corporation's optical data card,
- AT&T Corporation's non-contact memory card system,
- Micro Card Technology Inc.'s smart card system.

The overall design review and physical tests were structured in such a manner as to identify the strengths and weaknesses in these particular data carrier approaches. As such, the evaluation methodology used by the project team was slightly different for each system. The SDT prototype system supplied by Datakey Corporation was subjected to the most extensive set of physical tests. The remaining candidate systems were examined in less depth; these evaluations focused primarily on an overall design review and brief data integrity testing. Materials testing was conducted only on the current SDT prototype since this was the only device designed in the appropriate package.

2.2 Datakey System

The evaluation has been organized into the following sections:

- Description of the Datakey System,
- Results of the Data Integrity Tests,
- Datakey Materials Integrity Evaluation,
- Major Findings from the Evaluation.

2.2.1 Description of the Datakey System

The Datakey system consists of a tag interface device (HCPS-232) and the data tags and is shown in Figure 2.1. The reader is powered by a 5 volt adapter which plugs into a standard 120 V outlet. The reader communicates the data to and from the tag to a host computer with a serial data link.

The Datakey data tags are very similar in size to an Army metal identification tag. A picture of the tag electronics is shown in Figure 2.2. The data tag is encased in plastic with 8 notches molded into either side to allow access to the reader by the embedded electrical contacts. The contacts are recessed in these notches for protection from wear.

Each tag contains two separate integrated circuits. One is an 8-bit microprocessor, the 80C49, and the other is a SEEQ 64K-bit electrically erasable programmable memory (EEPROM). The microprocessor controls the data input and outputs from the tag, and data is stored in the 64K EEPROM. Power and data flow to and from the tag occurs through the eight contacts in the side of the tag.

The Datakey tag interface device (HCPS-232) is a small plastic box which houses the tag receptacle and the electronics necessary to manage data transfer to and from the tag. The dimensions of the box are approximately 5 x 5 x 2-1/2 inches. The box has openings for the tag, power cord, and serial link.

FIGURE 2.1 DATAKEY PROTOTYPE SDT SYSTEM

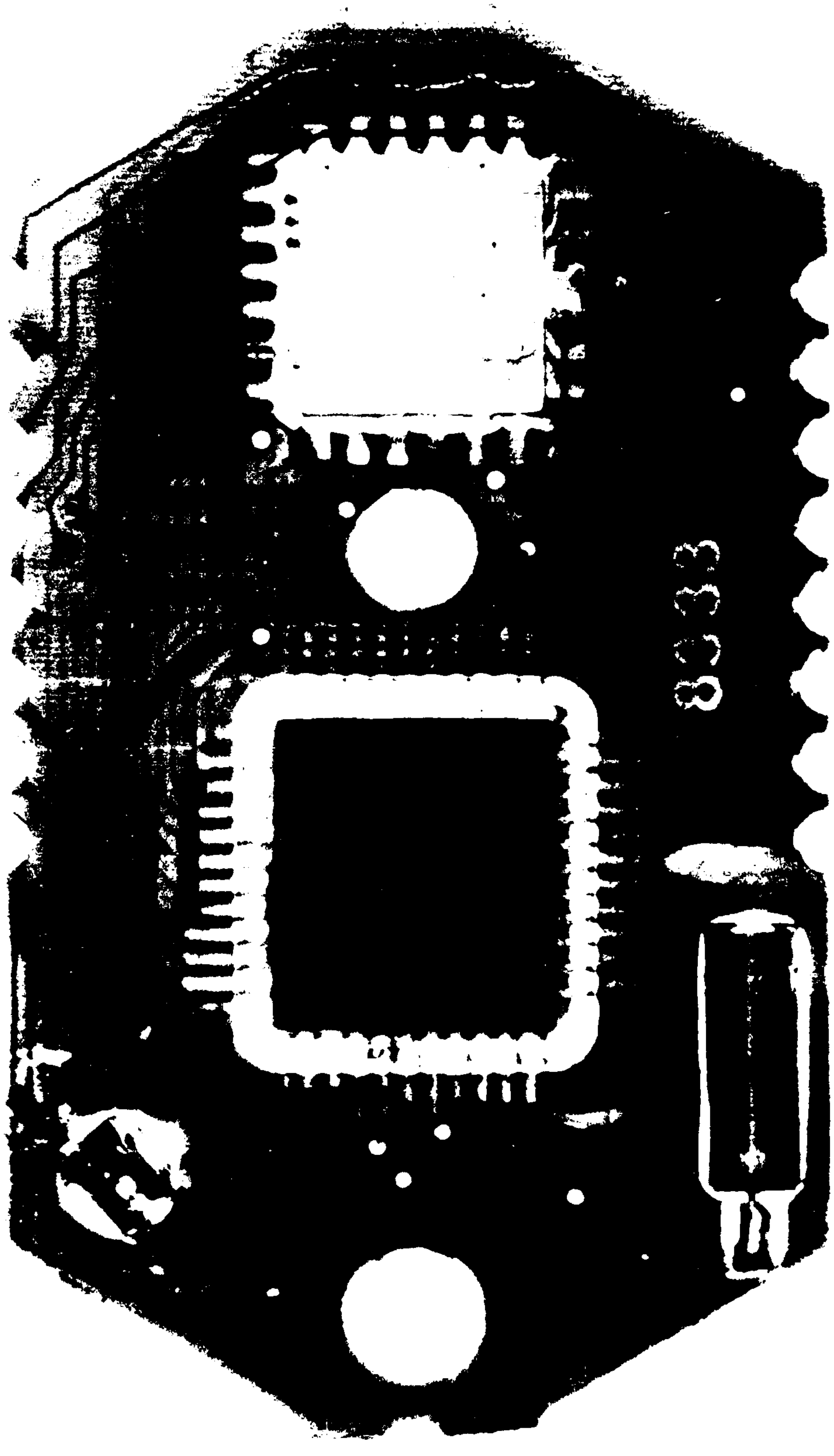

FIGURE 2.2 EMBEDDED ELECTRONICS IN SDT PROTOTYPE

The data tag receptacle contains spring loaded contacts which extend to make contact with the data tag. When the tag is fully inserted into the receptacle, there is a detent which holds the tag in place.

The reader communicates with a host computer through an RS-232 serial interface. The communication protocol, as designed by Datakey, consists of hexidecimal command codes sent from the host to the reader, and responses sent from the reader back to the PC. The reader is responsible for interaction with the microprocessor contained in the data tag.

The reader is controlled by a Motorola 8-bit microprocessor. The microprocessor has on-chip EPROM for program memory as well as on-chip RAM. Power is derived from a single 5 volt source. Circuitry within the reader converts the 5 volt signal to +/- 6.4 volts for the RS-232 serial communications link.

2.2.2 Results of Data Integrity Tests.

The variety of data integrity tests conducted were designed to identify any major shortcomings, and to help suggest improvements to future systems. As such, "lessons learned" regarding conditions that induce failure are often more important at this time than determining specific quantified values that cause the failure. The tests were designed to show trends of tag failure, and the number of tags tested did not allow for a true statistically significant experiment to be conducted.

2.2.2.1 Data Integrity Testing.

The method used for the evaluation of the Datakey data tag system was to load the tag with a pattern of known data, subject the tag to a stress test, then read the tag to see if the data was in any way altered. If the data reads correctly, the tag was considered to have passed that test. To accomplish these tests, the gas interface device was connected

to a Compaq portable computer system. A test program was installed in the computer and was used to load and read data, and make the data integrity comparisons. A listing of the software is included at the end of this appendix.

The data tags are subjected to a variety of harsh conditions including common solvents, temperature extreme, electromagnetic waves (EMI) and corona discharge, and vibration. A complete list of the tests performed follows.

TEST NAME: Rapid Hot/Cold Cycling **TAG TESTED:** Datakey

DESCRIPTION OF TEST:

This test was performed on one tag. The tag was alternately heated to 130 C (266 F) with a heat gun, then cooled with freon to -10 C (14 F). The cycle was repeated two times.

RESULTS:

The tag retained its data after this test.

TEST NAME: Contact Cycling and Alignment Sensitivity **TAG TESTED:** Datakey

DESCRIPTION OF TEST:

A tag was inserted, read, and removed from the tag interface device repetitively over a one-hour period (approximately 100 insertions). While in the read process, the tag was mechanically manipulated in an attempt to impact the data communication integrity.

RESULTS:

The tag showed some minor grooving on the end which enters the reader, but data was unaffected. Late in this test, the tag interface device suffered a mechanical failure in such a manner that it was unable to hold the tags in place during reading.

TEST NAME: EMI/ESD Testing **TAG TESTED:** Datakey

DESCRIPTION OF TEST:

These tests were designed to assess the effects of electromagnetic interference and electrostatic discharge (ESD) on the tag's electronics.

One tag was subjected to 10,000 volts of corona discharge.

Electromagnetic interference was provided from the electronic spark generation circuits in an automobile. This method was selected for two reasons. First, the transient nature and high spark energy provide a harsh environment for the tag. Secondly, exposure to this environment will be common in the objective system. (It should be noted that similar EMI can be found near motors and arc welders.)

Six tags from an early production run were subjected to EMI by placing them next to the spark plug wires of two different automobiles. Two others were shielded with metal ID tags and exposed to the same radiation. Four tags from a later production run were exposed to the EMI field of a spark plug wire. Two of these were shielded, two were not.

RESULTS:

The corona discharge did not affect the data integrity of the tag.

All of the six older tags failed the data integrity test. One of the old shielded tags failed, while the second one survived.

None of the newer tags were affected.

TEST NAME: Artificial Pocket Test **TAG TESTED:** Datakey

DESCRIPTION OF TEST:

This test was used to evaluate durability against moderate abrasion coupled with the soiling produced by the rubbing of metal coins over the surface of the SDT. The apparatus used for this procedure was an Eberbach Shaker. The shaker moves a mounted platform horizontally a distance of one inch in one direction of the starting point, then returns to the starting position to produce a back-and-forth shaking motion. At the low speed setting, the shaker produces 87-1/2 cycles (or 175 single coin rubs) per minute across the surface of the test area. The bottom of the pan was lined with Army khaki material.

The pan was then mounted to the Eberbach platform. A specific number of U.S. coins (20 quarters, 20 dimes, 20 nickles, and 20 pennies), was then added to the pan. (The calculated combined surface area of the coins approximately equals the surface area of the bottom of the pan). The shaker was operated at the low speed setting for a duration of 24 hours, or about 240,000 coin rubs. Electronic evaluations of the data tags were made at the end of the 24 hour test.

Four data tags from the first group (older series tags) and eight newer series tags were placed in the tray. The tray was shaken for 24 hours. This is approximately equal to two years wear in the pocket of the average individual. (See Figure 2.3)

RESULTS:

One of the older series tags failed to retain data while the others passed.

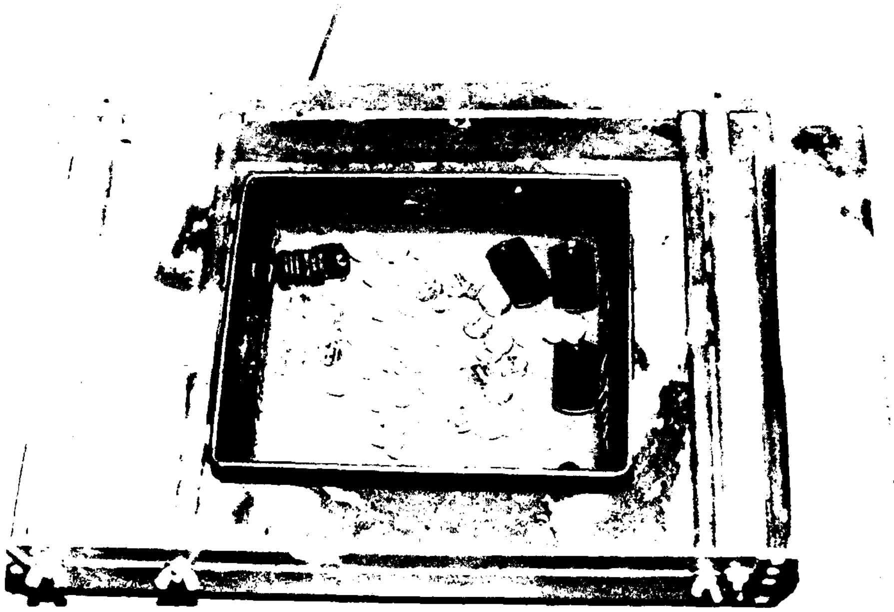

FIGURE 2.3 ARTIFICIAL POCKET TEST

TEST NAME: X-ray Exposure **TAG TESTED:** Datakey

DESCRIPTION OF TEST:

Two tags were exposed to x-rays, energy levels equivalent to a standard medical chest x-ray.

RESULTS:

Both tags retained their data. (The resulting x-ray image is shown in Figure 2.4.)

TEST NAME: Microwave Radiation **TAG TESTED:** Datakey

DESCRIPTION OF TEST:

One tag was placed into a microwave oven for 3 seconds.

RESULTS:

The tag material ignited and the package was destroyed.

FIGURE 2.4 RADIOGRAPH OF DATAKEY SDT PROTOTYPE

TEST NAME: Cigarette Lighter Burn Test **TAG TESTED:** Datakey

DESCRIPTION OF TEST:

A commercially-available Bic cigarette lighter was lit and held approximately 1/2-inch from the surface of the data tag for a five minute time period. After the burn test, the tag was noted to have a deformed shape along the edges. The sample was submitted for electronic evaluation. (See Figure 2.5.)

RESULTS:

The tag was sufficiently deformed that it was impossible to fit into the reader.

FIGURE 2.5 CIGARETTE LIGHTER BURN TEST

TEST NAME: Flame Test **TAG TESTED:** Datakey

DESCRIPTION OF TEST:

To simulate an accident of a person's clothing catching on fire while the data tag was being worn, another flame test was devised. A piece of khaki cloth cut from a pair of Army-issued military fatiques was soaked in kerosene and air-dried for approximately 20 minutes. The kerosene-soaked material was wrapped around the data tag and stapled to prevent it from unwrapping. The kerosene-impregnated material was ignited. The flame was allowed to burn for two minutes before the material was pulled away from the tag. The tag remained aflame approximately five seconds after removal of the cloth due to the kerosene remaining on the tag.

RESULTS:

The tag was charred and required cleaning and filing to make it fit into the reader. The data was unaffected.

TEST NAME: Ultrasonic Cleaning **TAG TESTED:** Datakey

DESCRIPTION OF TEST:

Two of the tags were placed into an ultrasonic cleaner with ammonia-based cleaning solution for thirty minutes while the unit was in operation.

RESULTS:

The tag data was unaffected.

TEST NAME: Physical Shock **TAG TESTED:** Datakey

DESCRIPTION OF TEST:

A tag was cooled to -10 C (14 F) with liquid freon, placed on a flat surface, then struck a moderate blow with a hammer. This test is especially harsh since the material becomes brittle at these temperatues and internal interconnects are likely to be affected by the shock. The test would simulate extreme conditions where a tag is subjected to high amounts of direct mechanical shock.

A second test was designed to determine the tag's ability to survive direct impact shock when struck with a sharp object. A tag was clamped in a vise and a sharp blow was delivered to the face of the tag with the end of a screwdriver hit by a hammer.

RESULTS:

When placed on a flat surface, the data was unaffected.

The point source impact test caused a small crack to appear on the opposite side of the tag. The tag's data could not be read by the interface device.

TEST NAME: Exposure to Common Solvents **TAG TESTED:** Datakey

DESCRIPTION OF THE TEST:

Tags were immersed in the following chemicals:

- ammonia
- artificial perspiration
- battery acid
- Coca-Cola
- copper/brass cleaner
- gasoline (unleaded)
- industrial cleaning solution
- insect repellant
- jet propulsion fuel
- kerosene
- methanol/water
- paint remover
- Prestone II Anti-Freeze
- salt solution
- sun screen
- Tide laundry solution
- transmission fluid

RESULTS:

Tags immersed in kerosene and paint remover did not survive. It was found that a small crack existed in the encasement material. This is the likely cause of leakage of the chemical into the electronics.

TEST NAME: Exposure to Decontamination Agents **TAG TESTED:** Datakey

DESCRIPTION OF TEST:

Tags were immersed in DS-2 and chlorine bleach at room temperature and 50 C (122 F).

RESULTS:

One tag immersed in DS-2 failed, while three immersed in the bleach failed. These results are summarized in Table 2.4 in the Materials Testing Section.

2.2.3 Datakey Materials Integrity Evaluation

The objective of this task was to evaluate the encasement material of the prototype SDT supplied by the DataKey Corporation. Many of these tests were destructive in nature, and would have resulted in the destruction of prototype tags. Since the main objective of the materials evaluation was to identify parameters for the encasement material itself, it was decided to perform most experiments on samples of the material only. Injection molded, tensil, flexural, and flatsheet specimen of polyphenylene sulfide, 1399X50479F, were obtained from RTT Corporation of Winona, Minnesota.

Experiments designed to quantify parameters about the tag materials used tests that closely resemble standard ASTM (American Society for Testing and Materials) procedures. The modified ASTM tests were conducted on standard ASTM bars of the material. There were two advantages to performing the tests of the samples rather than the electronic tags themselves: (1) The tests are not dependent on the unique geometry of a data tag and hence the results would be equally appropriate for new tag geometries, and (2) most of the tests are destructive, and a large dollar volume of tag inventory would have been destroyed through this testing.

2.2.3.1 Experimental Procedures

The tests were divided into three main categories:

1. environmental,
2. fuel and solvent resistance, and
3. chemical warfare and decontamination agents resistance.

2.2.3.2 Environmental Testing Procedures

The environmental tests included cold and hot exposure, hot and cold cycling, high heat and humidity conditions, and temperature cycling. The breakdown of each testing procedure was:

- Cold Exposure Conditions: -51 C (-60 F) for 72 hours
- Hot Exposure Conditions: 79 C (175 F) for 72 hours
- Hot/Cold Cycling Conditions:
  5 cycles total
  1 cycle = 79 C (175 F) for 2 hours/room temperature for 2 hours/-51 (-60 F) for 2 hours
- Cold Exposure/Hot-Cold Cycling Conditions:
  -51 C (-60 F) for 72 hours, then 5 hot-cold cycles (as described above)
- Hot Exposure/Hot-Cold Cycling Conditions:
  79 C (175 F) for 72 hours then 5 hot-cold cycles
- High Heat/Humidity Conditions:
  60 C (140 F) and 80% relative humidity for 72 hours

Tensile, flexural, notched Izod and flat stock specimen were placed at each of the above conditions. Specimen were compared in appearance, structure, and shape before and after exposure. After exposure to the various environments, the polyphenylene sulfide samples were evaluated for tensile and flexural strength, Izod impact (notched), and falling weight impact resistance. These ASTM methods were employed for the testing procedures:

Part 35	ASTM D 256 (Method A)	Impact Resistance of Plastics and Electrical Insulating Materials (Cantilever Beam-Izod-Type Test)

Part 35	ASTM D 638	Tensile Properties of Plastics
Part 35	ASTM D 790	Flexural Properties of Plastics
Part 35	ASTM D 3029(Modified)	Impact Resistance of Rigid Plastic Sheeting or Parts by Means of a Tup (Falling Weight)

Samples were evaluated in triplicate for the tensile, flexural, and Izod impact tests and standard deviations were calculated. Because of the limited number of flat sheets available, the falling weight impact value reported is the result of only one test specimen.

Equipment used for the physical tests are shown in Figures 2.6, 2.7, and 2.8.

2.2.3.3 Fuel/Solvent Resistance Testing Procedures

This testing involved subjecting the polymeric tests specimen and the SDT prototype to a variety of chemicals which the soldier may commonly encounter. The polymeric samples and the SDT prototypes were placed in a total of 17 solvents or chemical compositions, each for seven days, under ambient conditions. Specimen were compared in appearance and shape before and after exposure. The weight of the SDT prototype was also measured in order to determine weight gain or loss after exposure.

After exposure, the test specimen were evaluated for tensile strength, flexural strength, Izod impact (notched) strength, and weight loss due to sandpaper abrasion. A control sample which had not been exposed to the chemicals and values from the literature for a sample of Ryton R-4 (Phillips Chemical), which had no fillers or additives, were used for comparison.

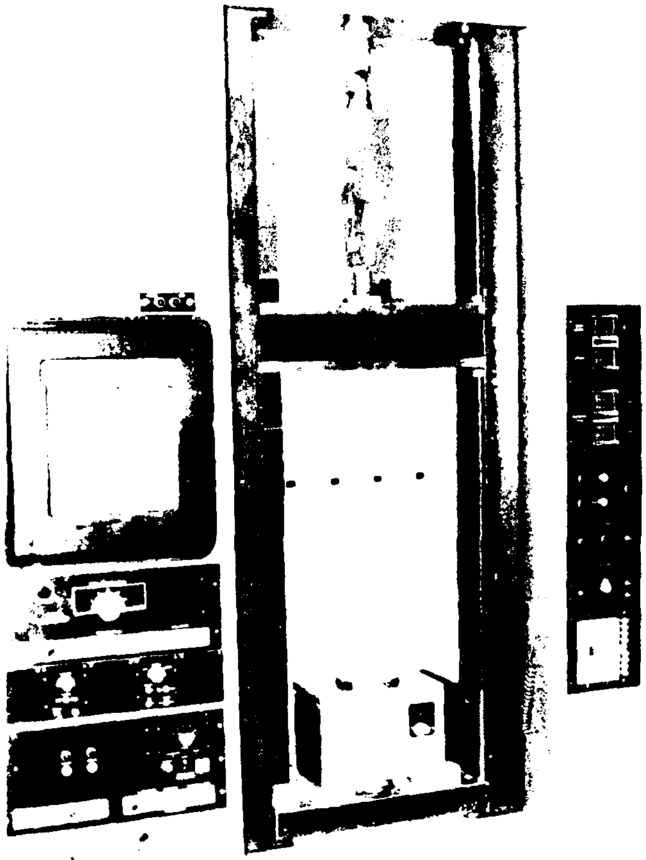

FIGURE 2.6 INSTRON TENSILE/FLEXURE TEST

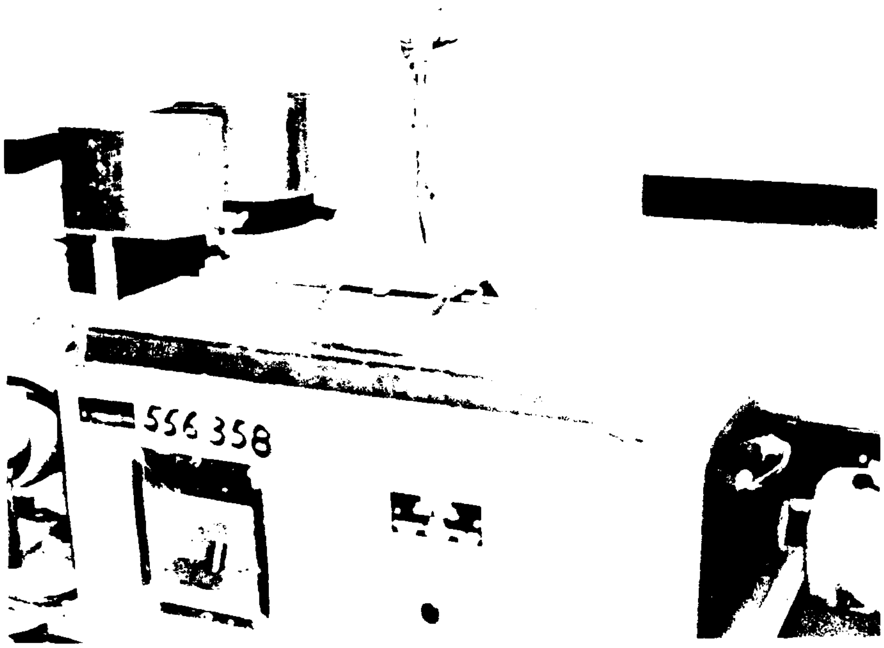

FIGURE 2.7 GARDNER WEAR TEST

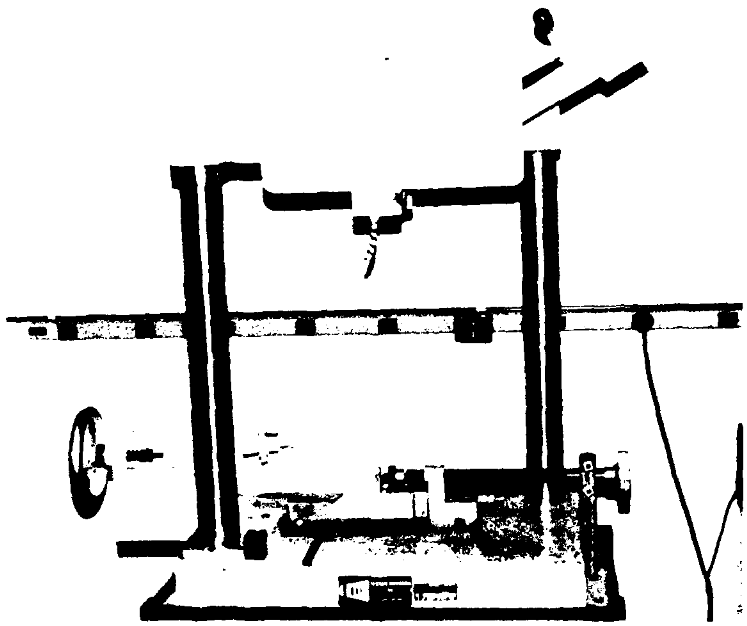

FIGURE 2.8 IZOD IMPACT TEST

Two tests--the sandpaper abrasion and the falling sand abrasion tests--were modified to conform with the polymeric materials tested and were not direct ASTM methods. Therefore these test procedures will be described in detail.

2.2.3.4 Sandpaper Abrasion Test

The purpose of this test was to determine the ability of the polymeric encasement to withstand grit abrasion without significant damage to the case. Using a Gardner Heavy-Duty Wear Tester, the following test was employed:

After the polymeric flat stock was removed from the solvents, it was attached to the base of the test apparatus by the use of double-sided tape. The arm of the apparatus (approximately 1 pound in weight), with a 2 inch x 3-1/4 inch flat surface was covered with 120 grit open coating sandpaper. This arm can freely move back and forth across the surface of the apparatus base in a scrubbing action. Polymeric samples were weighed, taken through 1300 cycles of scrubbing action (1 cycle = back and forth across the base of the apparatus), and reweighed. Because of the limited number of flat stock available, only one test specimen per chemical exposure was evaluated.

2.2.3.5 Falling Sand Abrasion Test

This test was used to simulate the soldier crawling through loose grit or dirt, and to evaluate the damage such action could cause on the contacts and the readability of the surface inscriptions of the SDT prototype. The apparatus used for this test is similar to the design shown in Part 27 ASTM D 968, Figure 2.9. A schematic drawing of the apparatus is found in Figure 2.9. During the evaluation, a 2-liter volume of natural silica sand with a particle size range between 20 and 30 mesh is dropped through a funnel to the specimen. The height of the funnel is

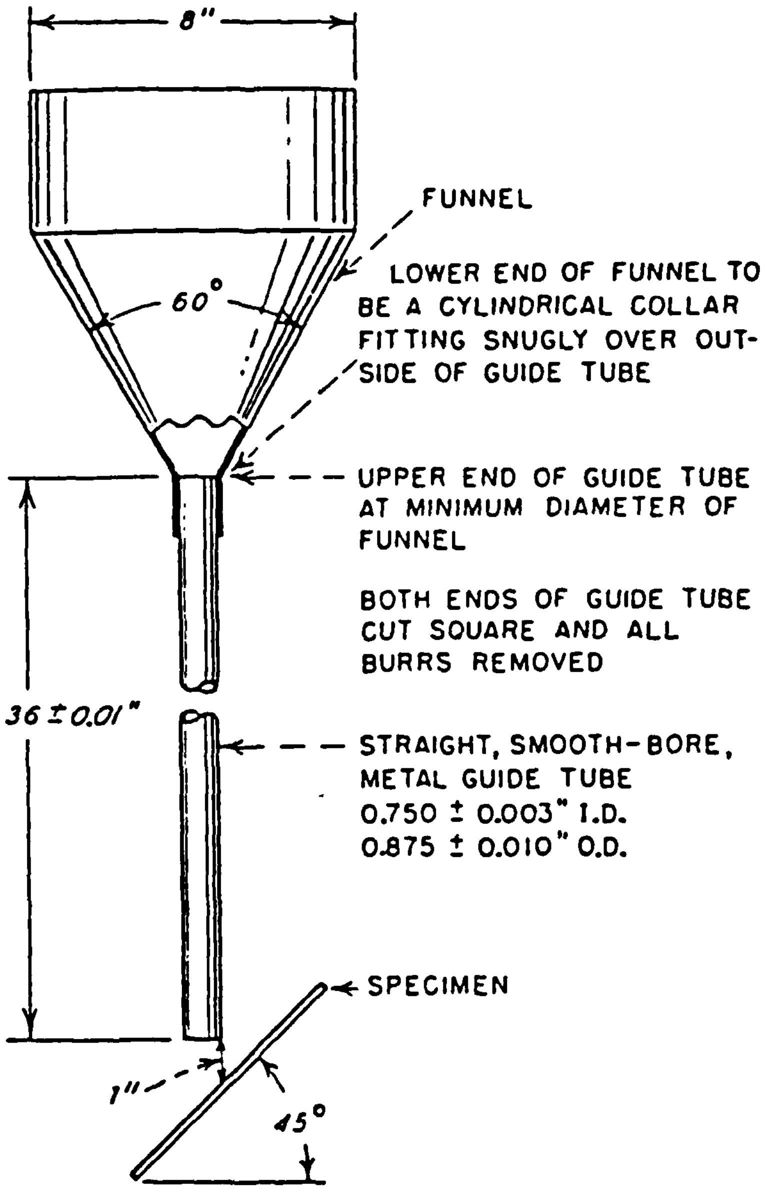

FIGURE 2.9 FALLING SAND ABRASION TEST

Figure from ASTM-D-968

37 inches above the specimen which is resting at an angle of 45 degrees to the vertical opening of the tube. Weight loss due to the sand abrasion and readability of the SDT prototype were measured.

2.2.3.6 Decontamination Materials Testing Procedures

The purpose of this work was to determine the effect of decontamination (decon) agents DS-2 and sodium hypochlorite solution (Clorox bleach) on polyphenylene sulfide test specimen and SDT prorotypes.

Conditions. The test materials were subjected to decon agents at 23 C (73 F) and 50 C (122 F) for 1, 6, and 24 hours before evaluation. The test matrix was:

	DS-2		Bleach	
	23 C (73 F)	50 C (122 F)	23 C (73 F)	50 C (122 F)
1 hour	3-tensile specimens 1-SDT	3-tensile specimens 1-SDT	3-tensile specimens 1-SDT	3-tensile specimens 1-SDT
6 hours	3-tensile specimens 1-SDT	3-tensile specimens 1-SDT	3-tensile specimens 1-SDT	3-tensile specimens 1-SDT
24 hours	3-tensile specimens 1-SDT	3-tensile specimens 1-SDT	3-tensile specimens 1-SDT	3-tensile specimens 1-SDT

Control samples were stored in air at room temperature conditions and in the 50 C (122 F) oven.

DS-2 was prepared using:

Diethylene triamine	70 parts by weight
Sodium hydroxide	2 parts by weight
Methyl cellosolve	28 parts by weight

The sodium hypochlorite solution was commercial Clorox bleach purchased locally. The tensile specimens, 1399X50479F, were supplied by the RTP Company.

A small hole was drilled near the end of each tensile test specimen and the specimen were fastened together at the top using small procelain fish-spine spaces and nichrome wire. This allowed access of the decon solutions to all surfaces of the test specimens. Three tensile specimens and one SDT were place in a glass-stoppered pyrex tube (4 cm diameter by 20 cm long). Twelve tubes in all were used. Six tubes were filled with DS-2 and six with Clorox. Three tubes with decon were stored at room temperature (approximately 23 C or 73.4 F) and three tubes with decon were stored in an oven at 50 C (122 F). After 1, 6, and 24 hours, appropriate tubes were opened and the samples rinsed with distilled water, dried and weighed SDT or tensile strength determined using an Instron Tensile Testing apparatus.

2.2.3.7 Chemical Warfare Agent Contamination Procedures

Battelle set up a methodology for gravimetrically measuring the sorption/desorption of gases and vapors by materials. The technique has been reported in technical literature for several years and is based on a quartz spring balance. Battelle's quartz spring sorption apparatus is pictured in Figure 2.10 and is in place at Battelle's U.S. Army approved chemical warfare (CW) agent laboratory.

In a typical sorption experiment, a test specimen of known dimensions and weighing in the range of 100 to 1000 mg., is suspended from each of two quartz springs (duplicate experiments) and the apparatus

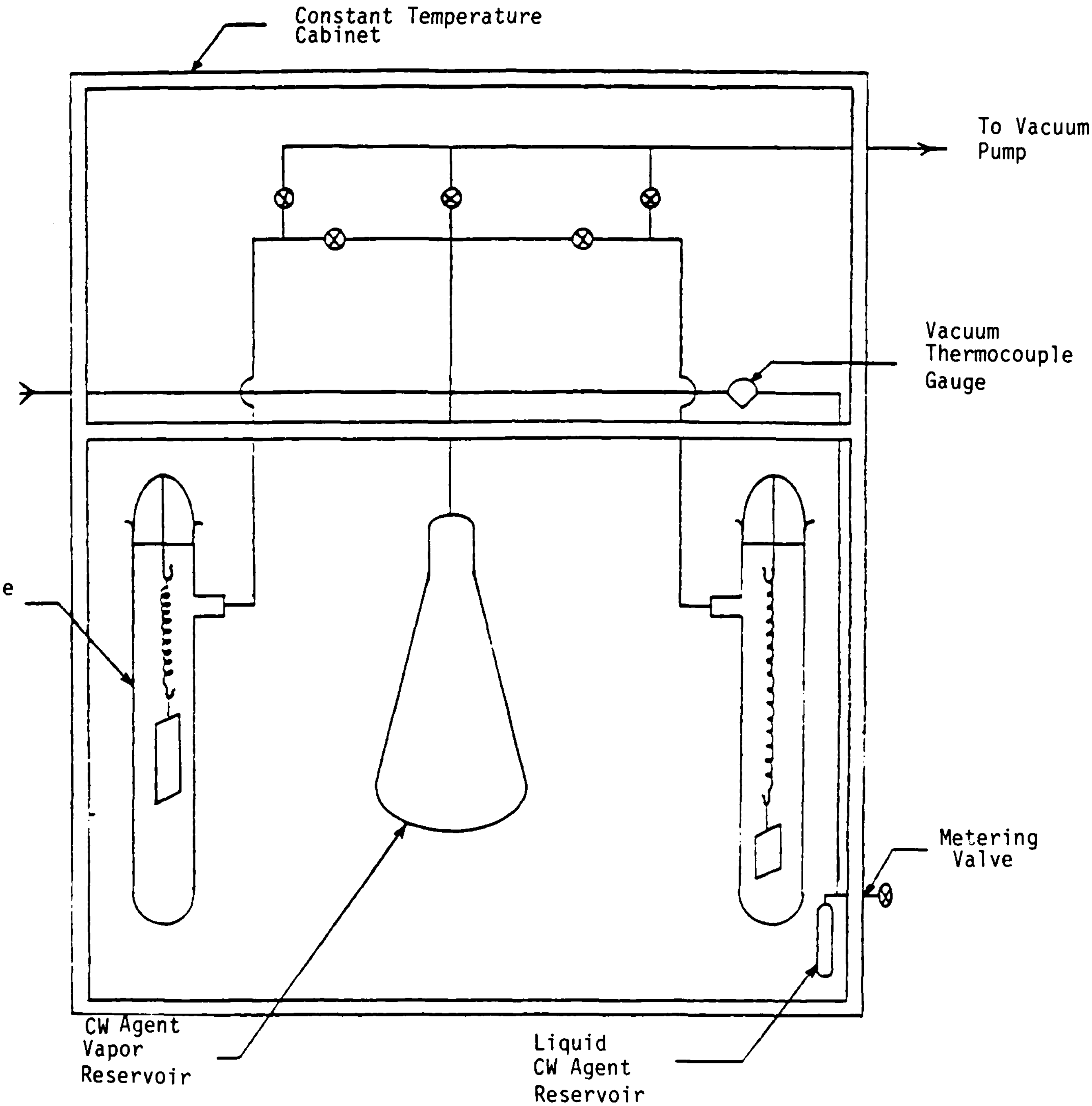

FIGURE 2.10 QUARTZ SPRING ABSORPTION BALANCES

is evacuated to about 0.02 torr. After several hours at 0.02 torr, the apparatus is isolated from the vacuum pump, and CW agent vapor (from the liquid reservoir) is introduced to the sample tubes (and 4 liter vapor reservoir) to the required vapor pressure. A Granville-Phillips pressure sensor with digital pressure display and a Whitey manual controlled metering valve allow the CW agent vapor pressure to be controlled to +/- 0.1 torr. In comparison to test specimen volume (sorption capacity), the 6 liter volume of the quarts spring apparatus is sufficiently large to ensure that the sorption process will not change the challenge vapor pressure.

Upon opening the sample tubes to CW agent vapor, the test specimens absorb agent and increase in weight. This weight increase is monitored by measuring the linear extension of the quartz springs with a cathetometer. The cathetometer is focused on a target at the sample end of the quartz spring, and the position of this moving target relative to a fixed reference (a graduation on a steel ruler) is measured. Relative measurements allow one cathetometer to be used to measure several springs under test at the same time and removes the variables of different observers and accidental "bumping" of the cathetometer. Depending on the cathetometer and spring combination used (springs calibrated at 0.05 mm or 0.002 mm are available), a maximum sensitivity of 13 micrograms can be obtained.

Prior to pump-down at the beginning of a sorption experiment, the liquid CW agent reservoir is placed under vacuum (and the CW agent degassed) by running at least three cycles of the following sequence: freezing the agent in liquid nitrogen, pumping-down on the frozen agent to about 0.02 torr and melting the agent while isolated from the vacuum pump. This procedure ensures that when the sample tubes are opened to the liquid CW agent reservoir, only agent vapor and no gases contribute to the controlled challenge pressure.

The quartz spring sorption apparatus is housed in a constant temperature cabinet; sorption/desorption rates can be obtained as a function of temperature within the range of about 10 C (50 F) to 60 C (140 F), controlled to +/- 1 C (+/-33.8). Temperature control is accomplished by an Omega temperature controller attached to a resistance heater and circulation of constant temperature water through a copper tube coil.

2.2.3.8 Materials Testing Results

The following section includes experimental results of all the tests to which the SDT prototype and the polymeric specimen were subjected.

2.2.3.8.1 Results of Environmental Exposure

Table 2.1 indicates experimental conditions and the physical property tests performed on the specimen. The data show that even after exposure to the various environmental conditions, the physical properties of the polymeric material are not significantly affected. Although the absolute value of the control sample is slightly lower than the exposed samples' values, the standard deviation indicated that the compared values are not significantly different.

The following table may assist in making a comparison of the reported data.

Tensile Strength (psi) (Specimen 1/8" thick x 1/2" wide)	Approximate Pounds to Break	Flexural Strength (psi) (Specimen 1/8" thick x 1/2" wide)	Approximate Pounds to Break
5,000	312.5	5,000	13
7,500	468.8	7,500	19.5
10,000	625	10,000	26
12,500	781.3	12,500	29.25
15,000	937.5	15,000	39

TABLE 2.1. PHYSICAL PROPERTIES OF 1399X50479F

Environmental	Tensile Strength (psi)	Flexural Strength (psi)	Izod Impact - Notched (ft-lbs)	Falling Dart (inch-lbs)
Hot Exposure (175 F/72 hrs)	11,636 ± 317	15,618 ± 366	1.10 ± .012	10 - Failure
Cold Exposure (-60 F/72 hrs)	11,543 ± 595	16,143 ± 583	1.02 ± 0	10 - Failure
Hot/Cold Cycling - 5 Cycles (175 F 2 hrs/RT 2 hrs/-60 F 2 hrs)	11,774 ± 739	16,678 ± 336	1.01 ± .012	10 - Failure
Cold Exposure (-60 F)/Hot/Cold Cycling	11,708 ± 584	15,639 ± 707	1.02 ± 0	10 - Failure
Hot Exposure (175 F)/Hot/Cold Cycling	11,475 ± 770	15,950 ± 948	1.03 ± .012	10 - Failure
Control	10,212 ± 824	15,874 ± 71	0.98 ± .03	10 - Failure

175 F = 79.4 C
-60 F = 51.1 C

For example, to break a PPS specimen (1/8 inch thick by 1/2 inch wide), which had a tensile strength of 10,000 psi by tensile (pulling), it would take 625 pounds of force. In comparison, an average male as a thumb and finger grip strength of 8-13 pounds (sustained and momentary hold, respectively). The arm strength that would coordinate with a pulling action is 42-56 pounds (See Figure 2.11.).[1]

Therefore the polymeric material can loosely be described as having a strength of approximately eleven times that which an average male arm could exert, even if the finger could continue to hold the grasp. There are no known values for human strength that would compare to the flexural strength values, but it is believed that the average male would not have enough finger strength to flexurally break the SDT prototype.

The Izod impact test is a useful method for comparing various grades of plastics. However, the Izod (notched) test is often not a reliable indicator of the overall toughness of a material. Some materials are notch sensitive, and an increased concentration of stress develops from the notching operations. The data in Table 2.1 indicates that the PPS has a low notched impact strength. Therefore the data could indicate the need to avoid sharp corners in the production of parts.

The falling weight impact test determines the energy required to crack or break a rigid plastic sheet under the impact of a free falling weight. Failure is signified by the presence of any crack or split created by the impact of the falling weight and can be seen by the naked eye. All of the samples listed in Table 2.1 were tested at 10 inch-pounds using a 1/2 inch diameter dart to make impact. All the samples were considered failures, since the reverse side of the flat polymeric specimen (the side away from the dart contact) exhibited surface cracks radiating from the center of the unsupported area of the specimen. Results of this test

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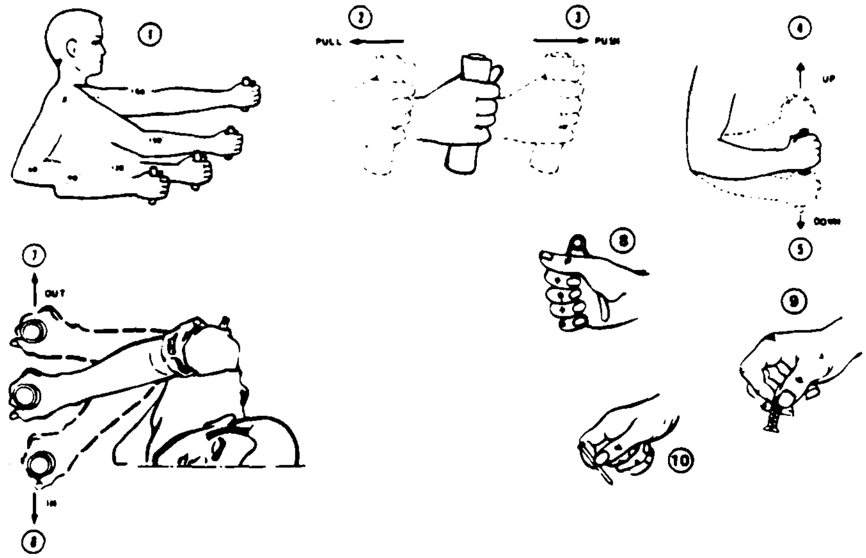
1. DoD Handbook 743 "Anthropometry of U.S. Military Personnel", MIL-STD-1472 C, Page 114, May, 1981.



ARM STRENGTH (Lb)														
(1)	(2)		(3)		(4)		(5)		(6)		(7)	
DEGREE OF ELBOW FLEXION (deg)	PULL		PUSH		UP		DOWN		IN		OUT	
	L	R*	L	R	L	R	L	R	L	R	L	R
180	50	52	42	50	9	14	13	17	13	20	8	14
150	42	56	30	42	15	18	18	20	15	20	8	15
120	34	42	26	36	17	24	21	26	20	22	10	15
90	32	37	22	36	17	20	21	26	16	18	10	16
60	26	24	22	34	15	20	18	20	17	20	12	17

HAND, AND THUMB-FINGER STRENGTH (Lb)				
	(8)		(9)	(10)
	HAND GRIP		THUMB-FINGER GRIP (PALMER)	THUMB-FINGER GRIPS (TIPS)
	L	R		
MOMENTARY HOLD	56	59	13	13
SUSTAINED HOLD	33	35	8	8

*L = LEFT; R = RIGHT

FIGURE 2.11 THUMB AND FINGER GRIP STRENGTH

indicate that a one pound sample dropped from a 10 inch height on an unsupported flat sheet sample would initiate some cracks in the polymeric material. It is possible that the smaller size molded SDT casing (with better support) could withstand higher impact forces.

2.2.3.8.2 Results of Fuel/Solvent Exposure

Table 2.2 indicates that the physical properties of polymeric samples after being subjected to various solvents or chemicals for seven days at room temperature. Once again, it can be concluded that the solvents had no significant effect on the tensile, flexural, or impact strengths of the samples. However, certain solvents did appear to affect the hardness of the PPS polymer. This can be seen from the weight loss data resulting from the sandpaper abrasion. It was expected that, if any of the solvents softened the polymer, the percent weight loss would be less than that exhibited by the control sample. If the polymer was hardened or became more brittle, the percent weight loss would be higher than that exhibited by the control. Of the 15 solvents and chemicals tested, only four appeared to have an effect on the polymer, and the effect was minimal. These include artificial perspiration, battery acid, copper/brass cleaner, and Prestone II antifreeze. No specific reason can be proposed as to why these materials affected the polymeric encasement. (The copper/brass cleaner and the antifreeze are both basic materials. Artificial perspiration is acidic (pH = 4.5) and the battery acid is a strong acid.) Therefore pH of the solutions is not a reason for the percent weight loss. This is also verified in the Ryton R-4 product literature. Ryton R-4 was subjected to 30% sulfuric acid at 93.3 C (200 F) for three months and retained 89% of its strength. Ryton R-4 maintained 86-90% of its strength in basic solutions for three months at 200 F. It is possible, however, that the chemicals are acting as solubilizing agents for an unknown low molecular weight entity in the PPS.

TABLE 2.2. PHYSICAL PROPERTIES OF 1399X50479F (ALL TESTS WERE PERFORMED IN TRIPLICATE EXCEPT WHERE INDICATED)

Solvents/Fuels	Tensile Strength (psi)	Flexural Strength (psi)	Izod Impact - Notched (ft-lbs)	Sandpaper[a] Abrasion (% weight loss)
Ammonia	11,619 ± 495	16,568 ± 284	1.0 ± 0	.067
Artificial Perspiration	11,196 ± 900	16,016 ± 464	1.0 ± 0	.045
Battery Acid (36% H_2SO_4)	11,602 ± 299	16,468 ± 318	1.0 ± 0	.034/.057[b]
Coca-Cola	11,372 ± 947	16,368 ± 388	1.0 ± 0	.097/.126[b]
Copper/Brass Cleaner	11,838 ± 515	16,111 ± 445	1.01 ± .02	.145
Industrial Cleaning Solution	9,410 ± 2220	16,769 ± 842	1.01 ± .012	.04
Insect Repellant	9,691 ± 1901	15,963 ± 292	1.0 ± 0	.11
Kerosene	10,171 ± 704	16,113 ± 550	1.01 ± .012	.08
Methanol/Water (90:10)	11,602 ± 938	16,902 ± 218	1.01 ± .012	.103
Paint Remover	9,965 ± 2023	16,493 ± 226	1.01 ± .012	.085
Prestone II - Antifreeze	11,073 ± 1040	16,268 ± 570	1.02 ± 0	.036
Salt Solution (10% NaCl)	10,567 ± 2325	16,335 ± 536	1.01 ± .012	.069
Sun Screen	11,200 ± 1135	16,625 ± 922	1.02 ± .015	.077
Tide Solution	11,673 ± 586	15,735 ± 575	1.03 ± .02	.082
Transmission Fluid	11,243 ± 363	15,793 ± 875	1.02 ± 0	.083
Control	10,212 ± 824	15,874 ± 71[c]	.98 ± .03	.08/.1[b]
Ryton R-4[d]	17,500	26,000	1.3	--
Data Tag Prototype	4,422 ± 390	--	--	--

(a) A single test except where indicated.
(b) Abrasion test was duplicated.
(c) Flexural test was performed on eight samples.
(d) Product literature.

Table 2.3 shows the results of exposure of the SDT prototype to 17 chemicals. (At the request of the project monitor, jet propulsion fuel, JP-4, and unleaded gasoline were added to the list of chemicals tested.) The data show that the paint remover produced the largest percentage weight gain of all the solvents tested. Also, the inscribed data from this tag was not readable. The tag was closely examined for defects in the casing.

The casing was also removed and the electronics examined. The data integrity of each tag after chemical exposure is described in the previous section on data integrity testing.

A data tag that had been soaked in kerosene also was not readable. The percent of solvent absorbed was not very large and it is not expected that the electronics will have been damaged. Because of the limited supply of tags available for testing, it was impossible to test a significant number of tags. It is possible that none of the solvents tested will affect the electronic operation of the tag. Therefore, before any conclusions can be made, this test should be repeated with kerosene and paint remover, using a statistically significant number of tags.

2.2.3.8.3 Results of Decontamination Evaluation

Chemical Agent Test. The sorption of saturated HD vapor by a 264 mg., rectangular sample (1.2 cm x 1.0 cm x 0.13 cm) of the data tag material was gravimetrically measured using a quartz spring balance. After about 6.3 hours of exposure, the sample sorbed 200 micrograms of HD (about 0.1 percent of the sample's weight). Results are noted in Figure 2.12. No further sorption was measured over an additional 184 hours of exposure to the saturated HD vapor. These sorption data are shown $(\text{minutes})^{1/2}$. This small amount of HD sorption probably will not degrade the mechanical properties of the data tag material and probably will not be a hazard (percutaneous or vapor) to the wearer. For comparison, after 24 hours of exposure to saturated HD vapor, the U. S. Army's chemical warfare agent resistant, polyurethane vehicle paint sorbed about 0.3 per cent of its weight (representing the equilibrium sorption amount).

TABLE 2.3. CHEMICAL EXPOSURE ON DATA TAG PROTOTYPE (7 DAYS IN SOLVENT AT ROOM TEMPERATURE)

Solvent/Fuels	Weight Gain[a] After Removal From Solvent (Percent)	Falling[b] Sand Abrasion (Weight Loss Percent)	Readable After Removal From Solvent
Ammonia	.125	.06	Yes
Artificial Perspiration	.085	---	Yes
Battery Acid (36% H_2SO_4)	.17	.06	Yes
Coca-Cola	.17	.07	Yes
Copper/Brass Cleaner	.13	.02	Yes
Gasoline (Unleaded)	.02	.001	Yes
Industrial Cleaning Solution	.05	.07	Yes
Insect Repellant	.16	1.1	Yes
Jet Propulsion Fuel (JP-4)	.005	0.0	Yes
Kerosene	.085	.09	No
Methanol/Water (90:10)	.19	.08	Yes
Paint Remover	2.49	1.0	No
Prestone II - Anti-Freeze	.19	.1	Yes
Salt Solution (10% NaCl)	.11	.05	Yes
Sun Screen	.12	.03	Yes
Tide Solution	.14	.05	Yes
Transmission Fluid	.19	.08	Yes

(a) Average of Duplicate Samples
(b) Single Sample

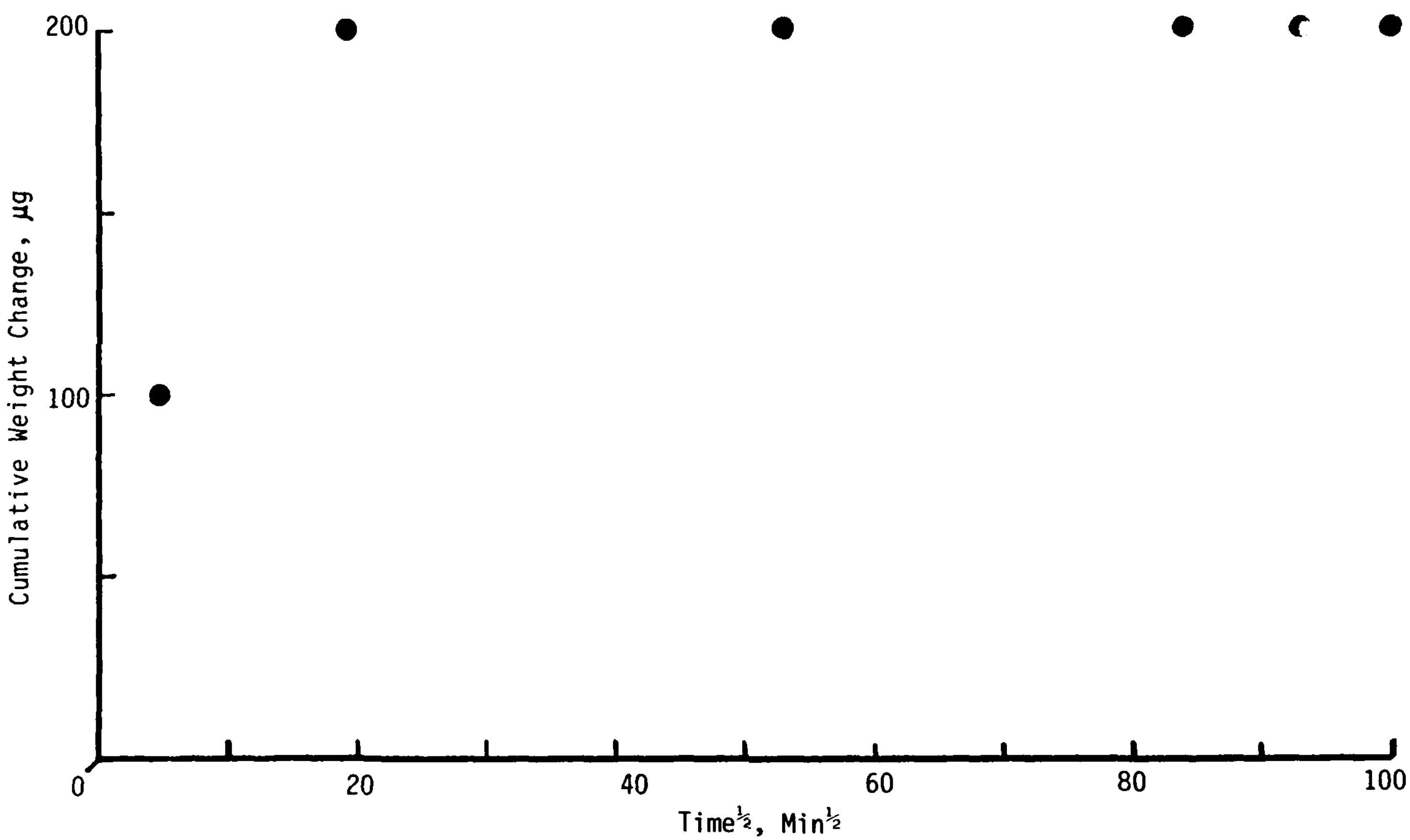


FIGURE 2.12 SATURATED HD VAPOR SORPTION BY DATA TAG MATERIAL

Tensile Strength. The results of the tensile strength determinations are shown in Table 2.4. Tensile strengths and standard deviation values are given for triplicate determinations.

Soldier Data Tags. The SDTs were weighed before exposure and 24 hours after exposure, following rinsing with water and drying. The 24 hour period was to allow the SDT, with its irregular contours, to air dry without the use of heat or hydrophilic solvents. The weight changes are listed in Table 2.5.

After 24 hours of exposure to bleach at room temperature, there was some corrosion product visible on the rivet and the appearance of slight corrosion on these contacts. After 24 hours exposure at 50 C (122 F) there was considerable corrosion products on the rivet, and blue or black corrosion product covering the contacts. Other exposed specimens were relatively unchanged.

2.2.3.9 Summary of the Materials Analysis

Tensile Strength. Exposure to DS-2 or bleach under any of the conditions tested did not result in significant loss of tensile strength of the polyphenylene sulfide test material.

SDT Weight Change. DS-2 caused somewhat larger weight increase for the SDT than did the bleach. Neither time nor temperature of exposure appeared to have a significant effect on weight gain. Therefore, the small weight gains in DS-2 may be due to retention of some of the decon agent in the contours of the SDT. The SDTs exposed to the bleach did show evidence of corrosion of the metal parts, especially after 24 hours.

TABLE 2.4. EFFECT OF EXPOSURE TO DS2 AND BLEACH ON TENSILE STRENGTH OF POLYPHENYLSYLFIDE

Temperature	Time, Hours	Tensil Strength, psi (std. dev.)	Temperature	Time, Hours	Tensile Strength psi (std. dev.)
		Decontamination Agent - DS2			
Room Temp.	1	11,400 (440)	50C	1	10,900 (950)
Room Temp.	6	11,200 (290)	50C	6	11,200 (200)
Room Temp.	24	11,000 (80)	50C	24	11,400 (160)
		Decontamination Agent - Bleach			
Room Temp.	1	10,700 (250)	50C	1	10,700 (400)
Room Temp.	6	11,700 (140)	50C	6	11,200 (470)
Room Temp.	24	11,200 (370)	50C	24	10,600 (60)
		Controls			
Room Temp.	-	11,400 (530)	50C	-	11,200 (360)

50 C = 122 F

TABLE 2.5. RESULTS OF EXPOSURE OF THE SDT TO DECON SOLUTIONS

DECON	Time (hrs)	Weight Gain (%)		Readable After Removal From Solution	
		Room Temperature	50C	Room Temperature	50C
DS2	1	.25	.26	P	P
	6	.29	.21	-	F
	24	.43	.27	P	P
Bleach	1	.06	.07	F	P
	6	.08	.08	P	P
	24	.03	.03	F	F

50 C = 122 F

P = Pass

F = Fail

2.2.4 Major Findings From the Evaluation

Based on the results of the physical tests and an overall design review, major findings from the evaluation have been itemized below.

2.2.4.1 Memory Technology

The Datakey prototype utilizes electrically erasable memory. This technology allows field alteration and erasure of the data on the tag. Because of the large number of transactions expected for each tag, field erasability is a highly recommended feature. Otherwise, the tag's life cycle will be strongly impacted by the transaction capacity of the on-board memory element. It is Battelle's viewpoint that electrically erasable memory is the most optimum choice for the Soldier Data Tag. The minimum data capacity for this element cannot be specified at this time and will require a detailed analyses of the information requirements for the various applications.

2.2.4.2 Materials

The materials used for the SDT prototype performed well in most of the physical tests. Using appropriate packaging techniques, the material provided excellent protection for the underlying imbedded electronics. One of the problems identified in the encasement material was microcracking. This situation led to data integrity failures during some of the solvent tests.

While the material is quite strong, laboratory experiments show that it is possible to create microcracks by placing a tag between the thumbs and exerting a bending force. While the tag encasement does not physically break apart, data tag electrical operation can be adversely

affected. (In one experiment, the bending motion applied by hand was great enough to cause an electronic failure in the imbedded circuits.)

2.2.4.3 Overall Reliability

Based on the evaluation, the Datakey data tag and interface device appear to have reliability deficiencies in several areas. Early production runs of the Datakey data tag appear to be highly susceptible to destruction from EMI. Tests indicate that EMI from automotive spark plug wires will destroy the tags if they are in proximity to the wire. This type of radiation is common around most motors, and high voltage electrical equipment. (Similar tests on later production runs did not exhibit these problems.)

Protection from EMI can be accomplished by adding a metal shield to the packaging of the tag. This is rather straightforward from the electronics standpoint, but requires consideration in the added complexity of packaging. EMI protection may also be possible by refining the layout of the tag to avoid any long printed circuit leads which might act as an antenna for EMI. This may involve changing the arrangement of the components within the package, or may involve changing to a microprocessor with EEPROM on the same chip to eliminate those interconnections.

The data tag from Datakey is not protected from high voltage at its input. Any high voltage applied at the inputs to the tag could damage the electronics contained in the tag and render the device unusable. A high voltage could occur from a power surge or from outright vandalism. The electronics can be protected by adding buffer electronics to all the input and output lines to the tag, or by making the tag interface non-contact. Electronics to protect the chips could be as simple as resistors to limit current and zener diodes to limit the voltage.

During the testing, Datakey interface devices experienced one failure of the mechanical tag receptacle and one failure of the electronics. The failure of the tag receptacle occured during normal use of the reader. Apparently, the detent within the receptacle used for holding the tag in

the reader wore out or loosened sufficiently so the reader no longer held the tags in place. This resulted in the tag being ejected while trying to read or write to the tag.

It should be noted that the tag receptacle is a weak link on the transmission of data to and from the tag. Any foreign material in the receptacle or on the tag could taucse the reader/tag contacts to fail. Contaminants which remain in the receptacle would be very difficult to remove from the spring-loaded tag retention system.

The electronic failure occurred from inserting a 12 volt adapter into the power input rather than a 5 volt one. The physical connectors from both power supplies were the same; this illustrates an installation concern since AC adapters for other electronic devices are common. The electronics were not adequately protected, and the reader failed. This problem could be corrected with an integral power supply.

The RS-232 interface from the reader to an external device utilizes an op-amp for the transmission of data. The output is +12/-6.5 volts under no load conditions. Under 3000 ohm load, the negative output drops to -5.8 volts. The positive and negative drive voltage is obtained with electronic circuitry in the reader. Although this design meets the basic requirements of the RS-232 standard, a more reliable design might have be achievable using standard RD-232 interface devices.

In general, the electronic design within the tag interface device appears to exhibit marginal operational performance. While it is certainly functional, common physical abuse that would be encountered through day to day operations can cause connectors to become loosened, and/or electronic components to fail. This design is not robust enough to survive the Army's application. This is also true from a mechanical housing standpoint. The enclosure and housed electronic boards must be reconfigured so that they can survive damage that would be sustained from a drop or exposure to environments with high moisture content.

2.2.4.4 Potential Security Vulnerabilities of the Tag System

The present Datakey tag exhibits several potential security problems. These problems make the tag's data vulnerable today. The encasement material can be removed easily from the present prototype without destroying the electronics. For example, it is possible to remove the case of the tag from the electronics in about 2 minutes with an Exacto knife. It was demonstrated that these tags were still usable with the case removed.

The ease of opening the tag indicates that it is likely that unscrupulous individuals would be able to alter the contents of the tag for their own gain. Because the plastic comes off the electronics easily, it is relatively simple to open the tag, change the data, and reroll the plastic case around the tag. Instructions describing the method for reading the tags computer program are readily available in the Intel-microcomputer data book. Once this program is known, data can be easily read and altered in the tag.

The electronics of the tag are insecure to destruction by anyone who desires to erase the information they carry. Since the power contacts to the microprocessor and memory are available to the outside world, it is relatively easy to apply high voltage to the contacts and destroy the chips. This type of destruction might be difficult to distinguish from normal tag failure.

2.3 Drexler Technology Optical Card System

2.3.1 Descrip+ion of the Optical Card

The Drexler Laser Card is an optical data storage system which uses laser light to read from and write to an optical data strip. The card itself is a polycarbonate and contains an optical strip. The optical data strip consists of a reflective silver media which is protected by clear plastic coating. In the prerecorded version, the card strip contains a photolithographed set of data that appears as bumps on the surface. In the field writable version, data is written to the strip by burning small pits in the reflective silver. In either case, these pits (or lumps) change the characteristics of reflected light when scanned across the surface. Data is encoded in this manner, and once written, cannot be modified. A photomicrograph of a section of the card is shown in Figure 2.13.

The Drexler Laser Card System is not yet a commercial product. Card production facilities have been completed and are capable of manufacturing high volumes of cards. However, card readers are still under development by several companies. The first U.S. application of the optical card is likely to be a health care card fielded by Blue Cross/Blue Shield. This test currently is expected sometime in 1986.

2.3.2 Results of Data Integrity Tests

The data integrity tests conducted on the Drexler Laser Card were strictly qualitative because there was no reader available to Battelle for this card. Tests were run by taking a photomicrograph of the prerecorded data on the card before a particular test was run, running the test, and then taking another picture of the data after the test.

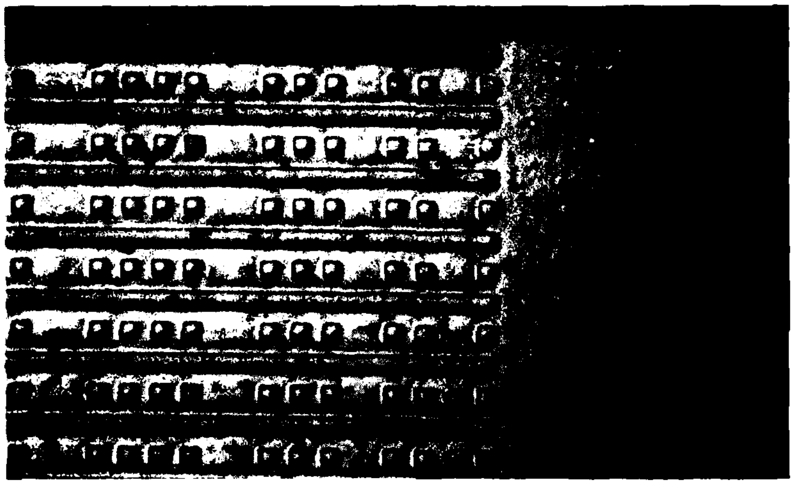


FIGURE 2.13 PHOTOMICROGRAPH OF DREXLER OPTICAL CARD

TEST NAME: Artificial Pocket **TAG TESTED:** Drexler Lasercard

DESCRIPTION OF TEST:

The laser card was placed into the artificial pocket (See similar Datakey test) containing coins and car keys. The tray was shaken for 24 hours. This is equivalent to two years in the pocket of the average individual.

RESULTS:

The photomicrograph of the data on the card showed no difference in the "before" and "after" photos.

TEST NAME: Rapid Hot/Cold Cycling **TAG TESTED:** Drexler Laser Card

DESCRIPTION OF TEST:

The card was alternately heated with a heat gun, and cooled with liquid freon.

RESULTS:

The data appeared unaffected.

TEST NAME: High Temperature Test **TAG TESTED:** Drexler Laser Card

DESCRIPTION OF TEST:

The card was heated until the plastic credit card started to melt.

RESULTS:

The data appeared unaffected, although the card was severely warped and impossible to read.

2.3.3 Major Findings From the Evaluation

Because of the lack of an appropriate reader, only a very brief, subjective evaluation with the optical data card technology could be performed. This was combined with Battelle's past experience and familiarity with such systems to arrive at the following findings.

2.3.3.1 Memory Technology

The optical data card technology provides the basis for storing extremely large amounts of data on a single plastic card. Cards under development today will have the ability to store two megabytes of data. While the data capacities of these systems is quite large, it is unlikely that they will possess the robustness necessary to survive the expected environment. Because the system uses a laser scanning technique to read and write data, it is necessary for the stripe to be unobscured during this process. In the SDT application, surface contaminants on the data tag will be unavoidable. It is logistically infeasible to expect that the tags must be cleaned prior to each transaction. Furthermore, because the memory media is on the surface, it will be subject to scratching. The vendor claims that minor surface scratches will not affect the reading and writing integrity of the system. However, major scratches on the surface are likely to result from a soldier's daily routine. These scratches would destroy the data integrity of the card.

2.3.3.2 Package Survivability

The Drexler Laser Card should have a survivability similar or greater than a normal credit card, because they share the same construction material. The lexan which houses the data strip is rugged and should be more robust than the card itself.

2.3.3.3 Security

The security of the Laser Card must be based entirely on data encryption because the data is readily available for reading. A possible security attack would involve copying the data onto a second card. While encryption may make direct interpretation of the data difficult, it may still be possible for a fraudulent user to initiate transactions with the counterfeit card.

2.3.4 Commercial Readiness

To date, there is no commercially-available reader for the optical data card supplied by Drexler Technology. Many companies are in the process of developing such a device, however the status of these developments cannot be determined. In addition, the end cost of the devices are likely to be more expensive than those required for electronic memory cards due to the complexity of the optical reading mechanism.

The optical data card systems, when commercially available, will represent a major step forward in portable information processing technologies. However, the characteristics of these systems appear to be incompatible with the overall requirements for the objective SDT system.

2.4 AT&T Memory Card System

2.4.1 Description

The AT&T Memory Card System is comprised of a plastic card with embedded electronics and a reader/writer device. The present system is designed for use in the pay telephone environment, where it will serve as an automatic dialing device. The card contains a 2000-byte electrically-erasable memory which contains frequently dialed numbers and credit accounts.

In this application, the user inserts his credit card-sized (approximately 0.030 inches thick) device into a pay telephone equipped with an appropriate reader and display system. The card and reader are shown in Figures 2.14 and 2.15. A menu appears on the display and allows the user to select items such as receiver volume, default credit account, and party to be dialed. In addition, the user can also enter new information into his card from the pay telephone terminal. Security for the system is provided through the use of a 4-digit personal identification number that must be entered prior to using the system. Failure to enter the correct number after a specific number of incorrect entries will cause the card to inactivate itself. When this occurs, the user must return the card to the place of issuance to have the information restored.

As described above, the AT&T Memory Card System is comprised of two basic elements--the card and the reader/writer. The basic element of the card is a thin wafer containing the electronics. These electronics include a custom-designed microprocessor, special analog interface circuitry, and an outboard memory. The card is assembled in a sandwich design with layers of plastic being applied to each side of the circuit board, and a layer of lexan film applied to the exterior which contains the graphics for the card.

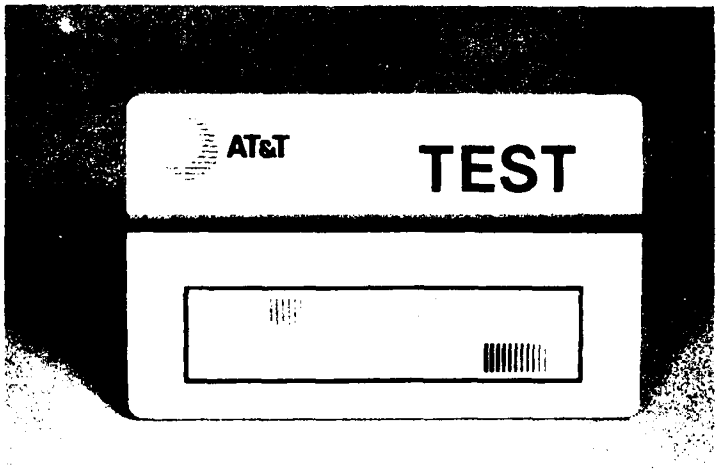


FIGURE 2.14 AT&T MEMORY CARD

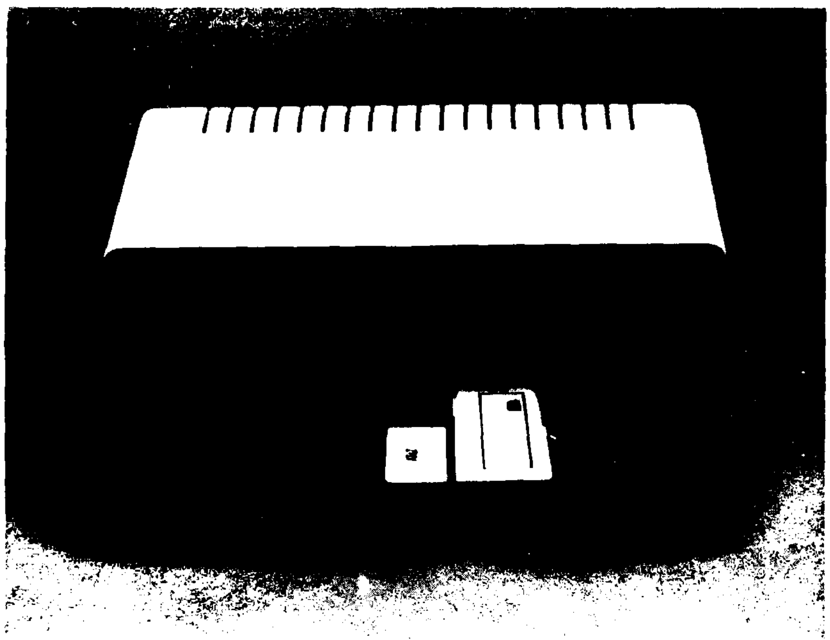


FIGURE 2.15 AT&T CARD READER

The AT&T Memory Card System uses a non-contact communication technique for the transfer of data and power. The external appearance of the card reveals no metallic contacts, such as those that would be found in conventional smart card systems (See next section). Instead, data communication and power transfer is established using a combination of capacitive and inductive coupling, respectively. Embedded within the card is a flat wound inductive coil that mates with a similar coil in the reader/writer. Power is transferred inductively into this coil and a special customized, analog integrated circuit within the card is used to convert this energy into a voltage compatible with the internal circuitry. Data is transferred to and from the card using pairs of capacitive plates embedded in the card that mate with a set of plates in the reader/writer.

The AT&T Memory Card System is designed to be compatible with the conventional magnetic stripe pay telephone cards. In order for the reader/writer to accomodate both magnetic stripe reading and non-contact memory card reading, this device must be able to sense which type of card is being inserted into its receptacle. This is accomplished by sensing the power delivered by the primary coil in the reader/writer. When the electronic memory card is inserted into the receptacle and its coil is properly aligned, power will be drawn by the card's circuitry. This transfer of power is sensed by the reader/writer and, consequently, the reader/writer determines that a non-contact memory card has been inserted into the receptacle and responds accordingly.

On the other hand, when the reader/writer has sensed that a card of some type has been inserted into the slot, but senses no power transfer through the primary inductive coil, it assumes that a magnetic stripe card (that has no embedded circuitry) has been inserted into the device. Magnetic read heads are then energized and the card is read as the user pulls the magnetic stripe card out through the receptacle.

A non-contact data coupling technique was selected by AT&T in order to meet the expected harsh environment of the pay telephone application. It was their opinion that a contact-based system would not be reliable due to contact corrosion and wear.

2.4.2 Data Integrity Tests

The AT&T Memory Card System is in the advanced prototype stage with design modifications still underway. The current package is not appropriate for the Army application--it cannot tolerate substantial flexure and is also probably too large. The current memory capacity (2,000 bytes) is less than the SDT prototype. However, the AT&T memory card system could be expanded to larger storage capacities through straightforward engineering changes.

As stated in the Battelle Phase 1 report, non-contact coupling is highly desirable in harsh environments. The AT&T card appears to have achieved this in a flat package that could be incorporated into a future SDT design. Therefore, the non-contact communication interface was the primary focus of the evaluation.

Several basic data integrity tests were conducted on the cards, and are described below. The overall evaluation is included in the "Major Findings" section.

TEST NAME: Rapid Hot/Cold Cycling **TAG TESTED:** AT&T Card

DESCRIPTION OF TEST:

This test was performed on one card. The card was alternately heated with a heat gun, and cooled with liquid freon.

RESULTS:

The card retained its data after this test.

TEST NAME: EMI Testing **TAG TESTED:** AT&T Card

DESCRIPTION OF TEST:

Two of the AT&T cards were subjected to EMI by placing them next to the spark plug wires of two different automobiles.

RESULTS:

The card retained its data after this test.

TEST NAME: Artificial Pocket Test **TAG TESTED:** AT&T Card

DESCRIPTION OF TEST:

One of the data cards was placed in an Eberbach Shaker (See similar Datakey test) containing coins and car keys. The tray was shaken for 24 hours. This is approximately equal to two years in the pocket of the average individual.

RESULTS:

The data card retained its data.

TEST NAME: Card Surface Obstruction **TAG TESTED:** AT&T Card

DESCRIPTION OF TEST:

Black electrician's tape was placed on both sides of the card to simulate foreign material such as dirt or paint on the card. This tape changes the gap between the card and reader which could affect data transfer. Obviously, very large gaps in card and reader would make coupling power and data impossible, but it is important that small gap changes be tolerated.

RESULTS:

The card was still readable.

TEST NAME: X-ray Exposure **TAG TESTED:** AT&T Card

DESCRIPTION OF TEST:

One of the cards was exposed to x-rays, energy levels equivalent to a standard medical chest x-ray. (See Figure 2.16)

RESULTS:

The card retained its data integrity.

TEST NAME: Physical Shock **TAG TESTED:** AT&T Card

DESCRIPTION OF TEST:

A card was cooled with liquid freon, placed on a flat surface, then struck a moderate blow with a hammer. This test is especially harsh since the material becomes brittle at low temperature and internal interconnects are likely to be affected by the shock. The test would simulate extreme conditions where a tag is subjected to high amounts of direct mechanical shock.

RESULTS:

The data was unaffected.

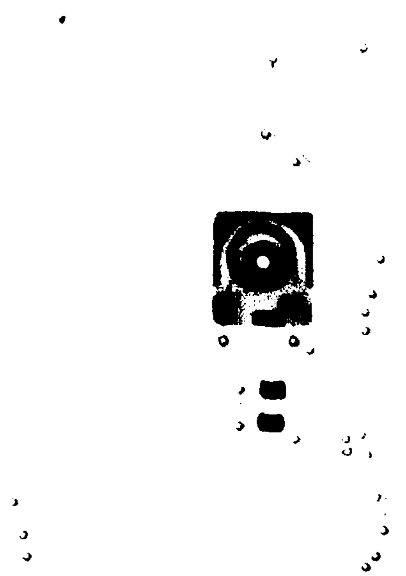


FIGURE 2.16 RADIOGRAPH OF THE AT&T MEMORY CARD SHOWING THE PLACEMENT OF ELECTRONICS

2.4.3 Performance Tests Provided By Vender

AT&T has conducted a set of tests on the card system as an aid to their own development process. This information was provided to Battelle to be included in the study.

The relevant test results are listed below. The card system survived:

- flexure: 6000 cycles of .400 inch deflection
- temperature/humidity cycling: -35 C (-31 F), 0 RH to 50 C (122 F), 95 RH, 10 cycles/day
- vibration/shock: 5 to 60 Hz at 1 g, 90 g, 11 msec
- electrostatic discharge: 2,000 volts

2.4.4 Major Findings for the Evaluation

Based on the data integrity tests described above and the overall design review, the following are the major findings from the evaluation.

2.4.4.1 Non-contact Communication Interface

The AT&T prototype is the first card-shaped portable data carrier system to use a non-contact communication interface. (It should be noted that other data carrier systems use this technology, however, none of the card-based systems are as commercially-ready as the AT&T card.) The feasibility of placing the necessary electronics in a flat package has been demonstrated by this device. While the package size is too large for the objective SDT system, engineering changes in the internal circuitry layout combined with consolidation of some of the electronic components could result in a non-contact system that could be incorporated into an SDT tag.

Because there is additional circuitry associated with the non-contact communication portion, cards based on this technology will have a

higher manufacturing cost than comparable cards based on metallic contacts. Even with this in mind, it is likely that this type of technology could be employed in a soldier data tag that would still be cost effective in the application.

2.4.4.2 Reader/Writer Design

The current AT&T reader/writer is well-engineered and robust. However, in its present form it may not survive the harsh environment expected in the SDT application. The unit should be hermetically sealed and the card receptacle slot should be easily cleanable.

A more desirable configuration of the reader/writer would be a surface reading mechanism instead of the card receptacle. The card receptacle is subject to a buildup of debris and would require maintenance. A surface reading device could be easily cleaned and virtually maintenance free.

A final consideration for the reader/writer is the development of a portable device for use in the field, such as medical applications. In cards with metallic contact, the portable reader/writer is relatively straightforward. A similar portable version for the non-contact reader/writer must be developed if this technology is to be employed in the objective tag system. In an earlier briefing provided by AT&T to Battelle, a portable reader/writer was shown to the project team but not demonstrated.

2.4.4.3 Physical Package

The current AT&T Memory Card package is probably not compatible with the Army's requirements. While it can be subjected to some degree of flexure, severe bending will destroy the internal components. In the card tested by Battelle, some of the critical components (in particular, the inductive coil) were placed in the center of the card. Since this area is subjected to the maximum bending stress, failures have been observed

by AT&T. A new design modification has moved these critical components to the edges of the card where the stresses are minimized. While this is an improvement over the earlier designs, the SDT application will require a smaller and more rigid device that will protect the internal circuits from damage due to mechanical stresses. An encasement material similar to that used on the current SDT prototype could be considered.

2.4.4.4 Overall System Reliability

Due to the time constraints of the project, the Battelle project team was only able to briefly examine the AT&T system. Data transfer between the card and reader/writer was accomplished reliably during the testing at Battelle. However, a problem with the reader/writer did arise during the final testing phase.

When an electronic memory card was inserted into the reader/writer, the device did not recognize that a non-contact card had been inserted. Instead, the reader/writer simply extracted the data from the surface magnetic stripe. This problem occured intermittently and its source was eventually identified as a faulty transistor interconnection on the circuit board. Resoldering of the connection solved the problem.

2.4.4.5 Security

The current AT&T prototype has an outboard EEPROM that is utilized in a similar manner to the data key prototype. As stated in the SDT evaluation, the use of two chips represents a potential security problem since the data in the outboard memory can be probed. Such a system would be incompatible with the objective SDT if security is a substantial requirement. A design change that incorporates the electrically erasable memory onto the microprocessor chip would reduce this security risk substantially.

2.5 Micro Card Technologies, Inc. CP8 Card System

2.5.1 Description

The Micro Card Technologies CP8 system is representative of the class of products referred to as "smart cards." It has been in existence for several years, and has seen its primary use in financial point-of-sale transaction systems. The most substantial use of these devices in the United States is the MasterCard trials taking place in Washington DC and Florida.

A CP8 card contains a custom integrated circuit that includes an 8-bit microprocessor and 21,088 bits of memory structured as follows:

- 12.8 K bits of read only memory (ROM)
- 288 bits of random access memory (RAM)
- 8 K bits of electrically programmable read only memory (EPROM)

The read only memory of the CP8 chip contains the control program which carries out all intrinsic functions of the CP8 card as well as communication with the connecting module. The random access memory is a set of registers used by the CP8 control program for storage of temporary data.

The electrically programmable read only memory provides 1,000 bytes for the storage of the following types of data:

- data used to manage memory space as accesses,
- personalization data (specific to an application and/or to the card bearer),
- transaction data, which may be written during the lifetime of the card.

Once EPROM data is written in a memory location, it cannot be erased nor rewritten. However, informaton stored in the card can be "changed" by writing a new value in a new location in memory. The application can interpret the most recent entries at the current state as well as examine previous states of the data. The indelibility of the EPROM memory provides a permanent portable file, and a complete audit trail of information written to the card.

Communication outside the CP8 chip uses a serial asynchronous interface between the CP8 chip and the connecting module, using a set of metallic contact that provide the following connections:

GND	Ground
Vcc	Operating power (read voltage)
Vp	Programming power (write voltage)
Clock	External clock signals for the CP8 chip
I/O	Bidirectional data transfer path
Reset	CP8 chip reset

Each of these lines correspond to one of the golden sectors on the visible chip support part of a CP8 card. The contacts are made of a thin coating of gold. Data transfers between the connecting module and the CP8 card takes place at 9600 bits/second.

2.5.2 Technical Evaluation

The Battelle project team attempted to procure a system from Micro Card for evaluation. Unfortunately, this equipment was not available in the time frame it was need for the project.

Battelle's evaluation of this technology was necessarily limited due to the circumstances noted above. However, because this technology is extremely relevant to the SDT application, a brief analysis of smart card systems was conducted for the study.

Micro Card supplied a standard set of technical documentation to Battelle in lieu of a hardware system. The project team was not able to conduct any physical evaluation of the system. The comments that follow are based upon a review of the documentation and Battelle past experience with smart card systems.

2.5.2.1 Security

The microcard system uses a single custom integrated circuit that is imbedded in the plastic card. The use of a single device makes data probing extremely difficult and provides a high degree of security of information on the card. This single chip approach would be highly desirable in an objective SDT system.

In addition, a four digit personal identification number must be provided to the imbedded microprocessor in order to allow data transfer to occur. A comparison of the entered PIN with one that has been previously stored in the microcomputer is performed entirely on the smart card. This also increases the access control security.

2.5.2.2 Memory Technology

The present CP8 card uses EPROM memory to provide an indelible data record that is permanent and provides an audit trail. The maximum number of transactions for the card is limited to several hundred in the current system. While this is appropriate for the credit card application (where this number of transactions may represent several years of card life), it is not appropriate for the Army application. Electrically erasable memory is more desirable since it permits obsolete data to be erased and replaced with a more current version of the soldier's file.

2.5.2.3 Package

The card shaped package for the CP8 device is driven by the current applications being pursued by Microcard. The actual electronic components are housed in a small circular device located in the upper corner of the card. Such a device could be easily repackaged into a data carrier that is the size of the current metal identification tag.

This device employs metallic contacts to provide data and power transfer. As noted in the previous section, contacts are not as desirable as a non-contact interface because of wear and corrosion problems. If contacts are to be provided on the SDT, then some method of insuring their integrity must be designed into the physical package.

3.0 CONCLUSIONS AND RECOMMENDATIONS

3.1 Summary of Technical Evaluations

This report has described an evaluation of several candidate technologies being considered for use in the Soldier Data Tag System. The technologies selected for evaluation are representative of existing off-the-shelf portable data carrier systems that are in, or near, commercial use today. It should be noted that many other companies also offer similar systems, and the specific systems reviewed in this report should, for the most part, be examined in the light of this fact. The major driving factor in the selection of specific systems was to procure them at reasonable cost in the time frame of the study.

Because each representative system was unique, a parallel design review and testing methodology was not appropriate. Rather, the review methodology was designed to evaluate the major strengths and weaknesses of the particular systems, in light of the anticipated Army SDT applications. Those aspects which were readily transferable to the objective SDT system were examined in detail (e.g., storage capacity, size of the processing element, communication techniques). Applications-specific aspects of the product which were not designed for the Army application were not evaluated in detail (such as packaging, appearance, etc.).

The following section summarizes the results of Battelle's evaluation.

3.2 Overall Evaluation of Technologies and Applicability to the SDT System

In the opinion of the project team, none of the systems reviewed can currently meet all of the anticipated Soldier Data Tag system needs. The current prototype system exhibits some reliability problems and non-

robust design techniques. The optical card is not yet a commercial-ready product and, hence, there are uncertainties about its performance in this application. Also, its data storage technique will probably not survive the environment. The memory card products are not properly packaged and may not exhibit the required storage capacity.

While the above comments reveal that a system is not commercially ready today, the objective SDT system is technically feasible. Engineering changes and a combination of various technologies are required in order to develop an Army SDT system that will meet the requirements. Based on the evaluation of representative technologies, the Battelle project team has identified a set of desirable technologies that should be considered for the objective SDT system.

3.2.1 Encasement Material Considerations

Based upon the tests conducted in this evaluation, it was found that flaws in the encasement material (such as microcracks), can allow the transfer of fluids into the area containing embedded electronics. A packaging approach that resists these flaws is necessary. The selected packaging material must not only be resistant to corrosive chemicals, but also have the ability to develop a hermetic seal around the electronics. It is conceivable that the development of the hermetic seal may be a multiple step process; that is, the embedded electronics may themselves be embedded within a protective material and then implanted into the final package. This approach would allow the SDT to take advantage of the strengths of different materials.

3.2.2 Communication Techniques

Non-contact data communication techniques are the preferred method over metallic contact-based interface systems. Metal contacts are subject to corrosion, wear, and obstruction. In the SDT environment, it

is likely that the tag will become dirty or be subjected to harsh, abrasive environments. While cleaning the tag and the reader would represent a solution to the problem, this is not logistically feasible in the intended environment.

A non-contact system that has no exposed contacts is more maintenance free. The system should be able to permit gapping between the tag and the reader and should also be insensitive to particulate matter that may obstruct the reading surface. Also, a reading system that does not require the tags be inserted into a receptacle, but rather laid flat upon a reader/writer pad is the most perferred. Such a system would be very easy to clean and simple to operate.

3.2.3 Electrically Erasable Memory

Portable data carrier technologies exist based on both erasable memory and non-erasable memory. It is expected that the soldier data tag will see a large number of transactions in its lifetime and that with each transaction, some portion of the internal memory will be updated. Because of this requirement, the tag must contain either an erasable memory or a very large amount of non-erasable memory. It is expected that the required amount of electronic non-erasable memory will not be cost effective in the SDT approach. (The optical data card can satisfy this requirement. However, for the survivability concerns mentioned elsewhere in this report, it is not considered as the memory technology for the data tag.) Therefore, an electrically erasable memory strategy should be employed in the card.

The data capacity of the storage element cannot be determined at this time. This determination can be made only after an in-depth analysis of the applications to utilize the tag is developed. It should be noted, however, that the 8K byte storage capacity of the prototype tag cannot be considered the minimum acceptable storage capacity. Through the use of standardized data coding and compression techniques, combined with the sharing of data among applications, it is conceivable that storage capacities less than 8K could be employed.

3.2.4 Tag Interface Device

The physical integrity of the tag interface device is of primary concern to the success of the SDT application. The device should be hermetically sealed and able to withstand moisture (rain, snow, etc.). In addition, its design should be robust, so that it can be dropped and subjected to severe mechanical shock.

The electronic design of the tag interface device should be robust and over-voltage protected. Installation of the reader/writer should be a simple procedures, ideally involving only the connection of a single cable to the host computer. A separate power supply that is external to the tag interface device is not a desirable feature. This increases the complexity of the installation, and reduces the overall reliability of the system.

3.2.5 Design Approach that Supports Technology Evolution and Migration

The overall SDT design philosophy should support technology evolution. For example, an initial system may be fielded with a low capacity tag. Once fielded, electrically erasable memories with larger storage capacities may become cost effective for the application. It should be a straightforward procedure to install these new memories into the same package and field the new tag without alteration to the reader/writers in the field. In order to support this type of evolution, both the SDT and the reader/writers must be designed with this in mind.

3.3 Recommendations

The development of the objective SDT system that meets the Army's requirements is technologically feasible today using a combination of technologies that can be found in commercially available data carrier systems. At this point in the development, it is recommended that the Army proceed with an in-depth requirements study to determine a specification for the objective SDT system. This should involve the following activities:

1. **In-depth analysis of the potential applications to determine information processing requirements.** This will enable the Army to determine the storage capacity requirement for the tag and the interface requirements for the tag interface device. Also, exact environmental specifications can be developed.
2. **Tag data base configuration study.** Once fielded, it is anticipated that a soldier data tag concept will attract new applications as well as isolated applications that will "piggyback" on the SDT. A method of data management must be adopted so that the applications can co-exist without destroying the information integrity of the tag system in general. The philosophy for this configuration should be examined in parallel with the applications study mentioned in Item 1.
3. **Market survey.** There are many portable data carrier systems available today that should be examined in light of the Army's application. The first step in this area would be to identify critical issues and criteria to be evaluated during the market survey. Following this, portable data carrier manufacturers should be interviewed in depth to determine their ability to satisfy the requirements.

4. **Demonstration experiments.** Continued demonstration experiments should be pursued using the existing prototype tags in order to quickly evaluate the operational concepts. In addition, demonstration experiments based on other off-the-shelf portable data carrier designs should be initiated to test alternative technical concepts.

SOFTWARE LISTING

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10 WRONG$ = "ABCDEFGHIJKLMNOPQRRTUVWXYZabcdefghijklmnopqrstuvwxyz1234567890"
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40 '*                 matt fleming                                     *
50 '*                 7/30/85                                          *
60 '*******************************************************************
70 OPEN "COM1:4800,N,8,1,DS0,CD0" AS #1
80 OUT &H3FB,11
90 TEST$ = "ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz1234567890"
100 FILE$ = "SDTAG"
110 'header -------------------------------------------------------------
120 '
130 CLS
140 PRINT "This is a testing program for the soldier data key."
150 PRINT "The program either loads the key with a standard test string,"
160 PRINT "or compares the standard test string to the existing data in"
170 PRINT "the key.  The standard string is:"
180 PRINT "ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz1234567890"
190 PRINT "BEWARE--- before the string is loaded into a new key, the key"
200 PRINT "is initialized to all zeros.  All data is destroyed."
210 '
220 INPUT ;"initialize new key or compare old key? [I][C]";ANSWER$
230 IF ANSWER$ = "I" OR ANSWER$ = "i" GOTO 310
240 IF ANSWER$ = "C" OR ANSWER$ = "c" GOTO 640
250 BEEP
260 CLS
270 GOTO 220
280 '
290 'initialization------------------------------------------------------
300 '
310 CLS
320 LOCATE 20,25
330 PRINT "initializing - wait about 10-30 seconds"
340 '
350 XMIT$ = CHR$(0)+CHR$(12)+CHR$(255) 'begin command
360 GOSUB 880
370 XMIT$ = CHR$(0)+CHR$(8)+CHR$(255)
380 GOSUB 880
390 CLS
400 LOCATE 20,25
410 IF SC$ <> CHR$(0) AND S2$ = CHR$(6) THEN PRINT "error";ASC(SC$)
420 PRINT "done initializing - now loading data"
430 XMIT$ = CHR$(0)+CHR$(12)+CHR$(255) 'begin command
440 GOSUB 880
450 XMIT$ = CHR$(0)+CHR$(10)+FILE$+CHR$(0)+CHR$(255) 'create file sdtag
460 GOSUB 880
470 XMIT$ = CHR$(0)+CHR$(0)+FILE$+CHR$(255) 'open the file
480 GOSUB 880
490 PAGE = 0
```

```
500 XMIT$ = CHR$(0)+CHR$(15)+CHR$(0)+TEST$+CHR$(255) 'send page
502 LOCATE 22,25
504 PRINT "page";PAGE
506 PAGE = PAGE + 1
510 GOSUB 880
520 IF SC$ = CHR$(0) AND S2$ = CHR$(6) GOTO 500
530 XMIT$ = CHR$(0)+CHR$(13)+CHR$(255) 'end command
540 GOSUB 880
550 CLS
560 LOCATE 20,25
570 PRINT "done with initialization"
580 CLS
590 LOCATE 21,25
600 PRINT "verifying tag pattern"
610 GOTO 670
620 '
630 'compare tag section ----------------------------------------------------------
640 CLS
650 LOCATE 20,25
660 PRINT "comparing tag to standard string"
670 XMIT$ = CHR$(0)+CHR$(12)+CHR$(255) 'begin command
680 GOSUB 880
690 XMIT$ = CHR$(0)+CHR$(0)+FILE$+CHR$(255) 'open the file
700 GOSUB 880
710 PAGE = 0
720 XMIT$ = CHR$(0)+CHR$(14)+CHR$(0)+CHR$(255) 'get previously sent page
730 GOSUB 880
740 IF SC$ = CHR$(14) AND S2$ = CHR$(6) GOTO 820
750 PAGE = PAGE + 1
760 LOCATE 22,25
770 PRINT "page";PAGE
780 IF P1$<> TEST$ THEN PRINT "error in page ";PAGE
790 IF P1$<> TEST$ THEN PRINT P1$
800 GOTO 720
810 '
820 XMIT$ = CHR$(0)+CHR$(13)+CHR$(255) 'end command
830 GOSUB 880
840 BEEP
850 END
860 ' transmit message to datakey ------------------------------------------------
870 '
880 P1$ = ""
890 PRINT #1,XMIT$;
900 X$ = INPUT$(1,#1)
910 P1$ = P1$+X$
920 IF X$<> CHR$(255) THEN GOTO 900
930 SC$ = MID$(P1$,3,1)
940 TP$ = MID$(P1$,4,1)
950 S2$ = MID$(P1$,2,1)
960 P1$ = MID$(P1$,3,LEN(P1$)-3)
970 IF S2$=CHR$(6) AND SC$=CHR$(3) THEN XMIT$=CHR$(0)+CHR$(14)+CHR$(1)+CHR$(255):PRINT "DATA ERROR":GOTO 88
980 IF S2$=CHR$(6) AND SC$=CHR$(2) THEN PRINT "TRANSMISSION ERROR":GOTO 880 ELSE
1000 XMIT$ = ""
1010 RETURN
```

END

DTIC

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